ROMANIAN ACADEMY
THE "COSTIN C. KIRIȚESCU" NATIONAL INSTITUTE
FOR ECONOMIC RESEARCH

THE RARE EARTHS ECONOMY. A NEW BRANCH OF ECONOMICS

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ECONOMIA PĂMÂNTURILOR RARE. O NOUA RAMURĂ A ECONOMIEI
Emilian M. DOBRESCU

THE RARE EARTHS ECONOMY. A NEW BRANCH OF ECONOMICS
Versiunea în limba engleză: Dr. George Cornel DUMITRESCU

Volumul de faţă
prezintă concluziile autorului desprinse din tema de cercetare cu acelaşi titlu,
realizată în cadrul programului de cercetare al Institutului de Economie Naţională –
Institutul Naţional de Cercetări Economice „Costin C Kiriţescu"
al Academiei Române

Coediţie

Bucureşti, România

CNCSIS: cod 045/2006
Editor coordonator: Valeriu IOAN-FRANC
Concepţie grafică, machetare şi tehnoredactare:
Luminiţa LOGIN

ISBN 978-973-159-161-2 2015

Motto: “Middle East has oil, but
China has rare mineral”
Deng Xiaoping, 1982

CONTENTS

PREFACE

The rare-earth elements (R) form the largest chemically coherent group in the periodic table. In addition to the 15 elements of chemical series called lanthanides (La to Lu), the yttrium (Y) and scandium (Sc) are frequently included in this group. The rare-earths are the key materials for a large number of technical applications. The presence of the rare-earth is essential in manufacturing hybrid vehicles, rechargeable batteries, wind turbine, mobile phones, flat screen display panels, compact fluorescent light bulbs, laptop computers, disk drives and catalytic convertors. The rare-earth-transition metal compounds are also the key materials for obtaining high energy permanent magnets. These magnets are used in electric motors for hybrid vehicles, miniaturization of hard disk drives used in many electrical devices or for spatial vehicles. Most efficient lighting as compact fluorescent lamps and display panels (LEDS, Plasma, LCD), require the use of rare-earth phosphors. One of the most effective rechargeable batteries is the lanthanum-nickel-metal hydride used in hybrid cars and many other electronic products. The rare-earths are used commonly for obtaining fluid-cracking catalysts. These are used in oil industry for separating various fractions from oil during the refining process. Catalytic convertors are also used for reducing toxic nitrogen oxides to harmless nitrogen and for oxygen oxidizing carbon monoxide to carbon dioxide and additionally oxidizing unburnt hydrocarbons.

The basic studies of the physical properties on materials based on rare-earths, is one of the main direction of research at international level. As above mentioned the scientific results were rapidly developed in connection with their technical uses. In addition, theoretical approaches were elaborated in order to explain the new and interesting features evidenced by the basic studies on rare-earth materials. World production of rare-earths in 2010 was of 133.600 tons. In 2015 year one estimates that global demand for rare-earth elements may reach 210.000 tones.

From historical point of view, the global rare-earth elements production, up to now followed four steps: (1) the monazite-placer era, starting in the late 1800s and ending abrupting in 1964; (2) USA era starting 1965 and ending about 1984; (3) a transition period from about 1984 to 1991 and (4) the Chinese era, beginning about 1991. The production of rare earths in China increased dramatically in the last years, being the greatest in the word. The deposits from two regions constitute the basic places of extraction. The most important is that from Inner Mongolia, the rare-earth contents in deposits being of 3 to 6 % rare-earth oxides, the reserves being more than 40 Mt. The second deposit is located in tropical southern China and contains a higher content of rare earth elements in ores, than in the first deposit.

The rare earth deposits are located also in Australia and Canada. There are also deposits in Romania. The exploitations of these deposits in our country can contribute significantly to development both of basic researches and their technical uses in many of the mentioned applications. Many products realized in our country, having high technical level, are based by rare-earth metals and oxides, imported from China, as high energy permanent magnets, catalysts, laser active media, ceramic products or metallurgy.

It is to be noted that the number of rare-earth deposits are rather limited in the world due to their geochemical properties as well as by environmental reasons. As example, for the last aspect, it is to be mentioned that monazite contains also thorium, the exploitation of corresponding ores being limited in some countries since their radioactivity.

The present book of PhD Emilian M. Dobrescu aims to develop a new branch of economics - rare earths economy and therefore its author was constructed a content and narration, which are included herewith. As we know, this paper is the first of its kind, which is based on facts - countries that have major deposits of rare earths, which process, the industrial countries, the main consumers of rare earths processed and the main beneficiaries.

In the race to build hybrid cars and wind turbines to feed growing demand for green technology, China has one clear advantage it holds the world's largest reserves of rare earth metals and dominates global production. Wind turbines, made by No. 2 wind turbine maker Xinjiang Goldwind Science & Technology and hybrid cars, being developed by Warren Buffet-backed Chinese automaker BYD are among the biggest guzzlers of rare earth minerals, which analysts say are facing a global supply crunch as demand swells.

This little-known class of 17 related elements is also used for a vast array of electronic devices ranging from Apple's iPhone to flat screen TVs, all of which are competing for the 120,000 tons of annual global supply. China controls 97 percent of rare earth production. “Rare earth for China is like oil to the Middle East,” said Yuanta Securities analyst Min Li. Worldwide demand for rare earth is expected to exceed supply by some 30,000 to 50,000 tons by 2012 unless major new production sources are developed, say officials at Australian rare earth mining company Arafura Resources. China has curbed exports of the mineral since 2005 through quotas and duties, saying it needs additional supplies to develop its domestic clean energy and high-tech sectors.

Chinese green companies would have priority in securing supply of the metals over international peers and their proximity to sources of the minerals ensures quicker and cheaper long-term supply. China's domestic consumption of the metals poses the biggest threat to global supply. The country, which holds a third of the world's reserves, eats up to 60 percent of global rare earth supply for a wide range of applications from consumer gadgets and medical equipment to defense weapons. China's trading partners have grown increasingly vocal about its move to cut its export quotas, but Beijing is determined to control the rare earth market. But while China may ensure its first-tier green companies are given access to the rare elements, analysts agree this alone is unlikely to guarantee success for the Chinese clean tech firms.

New technologies free of rare earth elements could emerge that may undermine China's advantage, while further cuts in rare earth quotas could trigger a political backlash which could force the nation to keep supply open for its trading partners. Chinese technology needs to develop quickly enough to make full use of that advantage. That window closes if its existing technologies fail to evolve. Still China will have the upper hand in the global rare earth market for a while yet.

There are currently many new mine projects outside of China in the pipeline but few will be able to compete with it on price unless governments offer production subsidies. Low prices for rare earth metals from China have undermined production and led to closure of several mines overseas. Lax environmental rules and cheap labor also allow China to sell rare earth metals at low prices. Also, the development of new rare earth mines could take as many as 10 years.

Like that of rare earth metals, lithium supply is expected to be tight by 2050, according to a European Commission study on critical raw materials. That is assuming most consumers would ditch their oil-guzzling cars for new generation vehicles. Also, a sister company of rival Toyota has secured a lithium supply deal in Argentina while

Toshiba Corp also plans to set up a rare metals joint venture with Kazakhstan state-owned firm Kazatomprom. Toyota, which makes the top-selling hybrid car Prius, and Nissan, maker of electric car Leaf, as well as, General Motors which designed plug-in hybrid Chevy Volt are most vulnerable to a rare earth supply crunch, analysts say.

A car like the Prius requires 1 kilogram (2.2 lb) of neodymium. And each Prius battery uses 10 to 15 kg (22-33 lb) of another rare earth, lanthanum. Siemens AG and General Electric, which are investing in the development of direct drive turbines for offshore wind generation, could also be facing risks in securing supply of the rare earth.

The author of these lines has studied for more than half a century the chemistry and physics of rare earth, these studies and papers was published in the prestigious scientific journals and in the international research journal. He has developed a pioneering in research, an achievement which is accepted in the domain recognized and cited by the greatest experts in the world.

Have you read these lines with pleasure and have you lead to the generation of new ideas in your field!

Cluj-Napoca, 2014, October 4 *Acad. Emil BURZO*

INTRODUCTION

For the first time in the field of economics, we use the syntagma ”rare earth elements” (REE) as a frontier discipline between economics as a generic science and the economy of rare earth elements, which studies the production, the distribution and the circulation of REE.

On our planet, over a quarter of the new technologies involved in producing economic goods use REE, also known as critical minerals. The industries based on these precious elements are valued at $5.000 billion, which represent 5% of the world GDP.

In the near future, the competition to control the reserves of REE will get tough. In the 21st Century, REE are as important as oil was for the previous century and coal for the 19th Century, namely, the engine of a new industrial revolution.

The energy of the future will be generated with equipment made out of steel, concrete, non-ferrous metals, and also rare earth elements. The scale development of the new technologies will boost the demand for this resources. It is worrying that the reserves of REE are scarce in Europe and other developed countries such the US and Japan and abundant in China, which in the past five years became, almost, the only producer. The technology used to produce REE is complex and very polluting.

Rare earth elements represent a new concept and become an important part of our daily life, given the increased use of smart devices. In 1982, the public awareness on REE was almost nonexistent. Only few decision makers from the military and intelligence fields were familiar with it. Civil and military high-tech applications (smart weapons, TVs, computers, smartphones, permanent magnets etc.) make this critical minerals very desirable (see Table 1 in the annexes).

The E.U., the U.S., Japan and an increasing number of emerging countries (BRICS etc.) depend on the availability of REE, which are of paramount importance for their economic and military development.

Discovered in the 18th Century, REE are not that “rare” in the proper sense of the word. They are available in larger quantities then copper, gold, lead or platinum, but mining them is difficult due to low percentage of REE in the carrying minerals. The world production of REE is about 150.000 tons per year, very modest in comparison with the iron production of 2.3 billion tons per year[1]. For electronics and the green industries these minerals are of vital importance.

REE are accounted as the 5th strategic raw material after water, steel, oil and rubber.

Many strategic battles during the World War II were carried out in order to get the control over oil reserves (Eurasia) or rubber production (south-east Asia).

In the last three or four decades, the regional wars in Afghanistan, Iraq, Iran were waged for the same reasons (oil and REE) as we argue in our book.

[1] The US Geological Survey, 2011.

Chapter 1
RARE EARTH ELEMENTS
- GENERAL CHARACTERIZATION -

In Mendeleev`s periodic table, 15 out of 17 rare earth elements can be found in the lanthanide series which comprises the chemical elements with atomic numbers from 57 to 71, starting with lanthanum and ending with lutetium. The other two are scandium and yttrium, considered as transition metals.

1.1. Important metals in comprised in the rare earth elements

In nature, it is difficult to find pure REE oxides, in rich concentrations. The enumeration of the chemical elements from the lanthanide series sounds like reciting from Latin language: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium.

The REE were discovered in 1787 by a Swedish lieutenant. Most of the rare earth elements are pretty common and more abundant in the earth`s crust than lead or gold.

The deposits of REE can be found mixed with precious metal deposits. This fact was noticed in the State of Carolina in the U.S., during the gold washing process. The slit resulted was very rich in monazites[1].

Most permanent magnets contain neodymium or cobalt-samarium. The advantage of neodymium magnets consist in their low mass, high reliability and excellent magnetic properties. This magnets are very brittle and vulnerable to corrosion. In order to protect them from breaking they are coated or plated.

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[1] Paul Truchot, *Les terres rares: mineralogie, proprietes, analyse,* Paris, G. Carre şi C. Naud, 1898, p. 29.

Samarium-cobalt magnets are recommended to be used for high temperatures applications due to their high stability. This kind of magnets don't corrode and they are resistant against acidic or basic liquids. This magnets can be produced by means of casting, cold pressing or sinterization. The rare earth based magnets have the highest magnetic energy known at present. From economic standpoint, REE belong to the group of strategic metals. As we mentioned, they are not as rare as their name suggests, being abundant in the earth`s crust. For example cerium it's as spread as copper. Thulium is the rarest. In the last decades the demand for rare earths increased due to the development of high-tech technologies and industries (see chapter 4).

The REE have a metallic appearance, they are soft, malleable and ductile. These elements are chemically reactive, especially at high temperature or when they are finely divided.

The name "earth" comes from the fact that REE were discovered in minerals the old French word for oxides.

Given their geochemical properties, they are very unevenly distributed in the earth's crust, often in concentrations that are not profitable for mining. The Swedish chemist Jöns Jacob Berzelius (1779-1848) divided the lanthanides into two subgroups depending on the solubility of their sulfates:

a. Cerium`s subgroup (cerium, lanthanum, praseodymium, neodymium, promethium, and samarium) with atomic number from 57 to 63;

b. Yttrium`s subgroup (europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium) with atomic numbers from 64 to 71.

The world reserves of REE are estimated at 45 megatons.[2] Among them, lanthanum and neodymium are more abundant than lead and cerium is more spread than tin or zinc. Few experts know that thulium and lutetium are 200 times more abundant in the earth`s crust than gold, according to the satellite prospections of the US Geological Survey.

The REE don`t exist as separate elements in or on the earth`s crust, but only in mixtures of about 150 known minerals , with specific spread for each of it.

[2] US Geological Survey, 2011.

Rare earth elements have the same external electronic configuration and therefore similar chemical properties. The lanthanides, also called transition elements, differ only by the structure of an internal electronic layer. This feature explains their association in the group and the fact that they have similar chemical and physical properties.

Their great affinity for oxygen translates into a significant pyrophoricity of the metal as through a great stability of the chemical bond between REE and oxygen.

REE easily combine with anions to make soluble salts (chloride, nitrate) or insoluble salts (sulfites, fluorides, carbonates, oxalates, phosphates); can be also used to make synthetic mineral compounds (borates, molybdates, silicates) and can be bond in two or more distinct layers through organic molecules in order to make very stable compounds.

We must distinguish between rare earth elements and rare metals. These are two distinct categories of substances, even if the first one generates the second one. To avoid the confusion, the experts use the syntagm of “critical metals”. In general, REE can`t be found in pure concentration in nature.

In 2010, a committee of E.U. experts classified the 14 “critical metals”, extracted by means of various technologies from REE, vital for the production of new goods (see chapter 4). Between 2006 and 2012, China exported 97 percent of the “critical metals”. The critical metals are the least recyclable and for now apparently can`t be reused.

Most of the world reserves of REE consists of two minerals: 1) bastnasite which contains cesium, lanthanum, ytterbium, and can be found in China and the U.S.; 2) 4 kinds of monazites (with cesium, lanthanum, neodymium, and praseodymium) which can be found especially in Australia, Brazil, China, India, Malaysia, South Africa, Sri Lanka, Thailand and the U.S..

Other minerals containing REE are:

- apatite $Ca_5(PO_4)_3(F,Cl,OH)$;
- cheralite $(Ca,Ce)(Th,Ce)(PO_4)_2$,
- eudialyte $(Na_{15}Ca_6(Fe,Mn)_3Zr_3SiO(O,OH,H_2O)_3(Si_3O_9)_2(Si_9O_{272}(OH,Cl)_2$,
- loparite $(Ce,Na,Ca)(Ti,Nb)O_3$,
- phosphorite $3Ca_3(PO_4)_2 \cdot Ca(OH,F,Cl)_2$,
- clays (extracted through ionic absorption);

- secondary monazite;
- residues of uranium solutions;
- xenotime.

In the past there were no separation technologies for the various metals and REE, which had only limited use. Due to the modern technologies, now all rare earth elements can be separated and transformed in economic goods (batteries for electric cars and smartphones etc.) Therefore, the battery factories increased their demand for lithium, a vital raw material for durable, quality products.

1.2. The importance of the "critical metals" for the world economy

In the study "Minerals, critical minerals and the U.S. economy"[3], the National Research Council recommended the US Government to take the necessary steps to secure the the supply of non-energy minerals, considered critical and strategic to the U.S. economy. The study analyzes all the risks:

– the availability of REE extracted with the current technologies;
– the substitution degree;
– the political risks in the international trade with strategic and critical resources;
– the U.S. defense policy and the strategic importance of some minerals for civil, but mainly for defense technologies.

The above mentioned study was taken as reference by other interested parties. The European Commission is working on a viable strategy regarding the raw materials. In this regard, the Commission will assess every two years the progress made in order to identify the problems occurred and to correct ineffective measures.

When they were discovered, back in the 19th century, the rare earth elements were considered as some of the most special materials on the planet. As we mentioned the REE are relatively abundant. However, the operational and environmental costs are very high. That`s why only the rich deposits worth being operated. The rare earth elements are, by their nature, malleable and have high electrical conductivity.

3 National Research Council. *Minerals, Critical Minerals, and the U.S. Economy*. Washington, DC: The National Academies Press, 2008.

Their process of extraction consists in dissolving the mineral in liquids like water and acidic solvents.

As we mentioned, there are 17 rare earth elements, each very important for the production of hi-tech goods such as batteries, smart TVs, smartphones, notebooks, seismic monitoring equipment, nuclear reactors, rockets etc.

Terbium is a natural signal amplifier being used to manufacture optical fiber cables. Also when compressed it generates a change in the electrical circuits and for that feature is used in the production of earthquake detectors.

The REE are combined in alloys to make strong magnets which are used to manufacture wind turbines. The magnets are crucial parts of electric generators, and they help transforming the rotation movement of the propellers into electricity.

Dysprosium, another rare earth element is used to produce advanced electric motors and the battery systems of the hybrid cars, because the magnets comprising this element are much lighter and therefore more efficient. The fact that dysprosium absorbs neutrons makes it valuable in nuclear reactors to control the availability rate of the neutrons. Due to its magnetic properties dysprosium is also use to mass-produce cd players.

Cerium is used in the fabrication of catalytic converters that reduce the carbon dioxide emissions of the vehicles. Praseodymium gives the yellow color to ceramic alloys.

REE deposits are abundant, but the risk of not having them available for the dependent industries is still high, considering their strategic importance. In order to compensate the decrease in the international supply, due to the Chinese trade policies, it is essential to rapidly make operational the new deposits discovered, especially the ones in Afghanistan (see subchapter 3.2) or to discover new ones. Afghanistan`s infrastructure is very poor and the costs to start operating the deposits will be high. To finance projects in these difficult times will also be a great endeavor.

The economy of such materials and the manufacturing technologies involved, some of them very recent, as we mentioned, make difficult the replacement REE. Permanent magnets made of neodymium have qualities that make them irreplaceable with the classical ones, based on ferrite, with lower performances. The car batteries based on nickel metal hydride (NiMH), comprising lanthanum can be progressively replaced with batteries based on lithium-ion (Li-ion).

Chapter 2
PRODUCTION OF RARE EARTH ELEMENTS

During the last ten years, the production of rare earth elements has increased 5 times, from 40.000 tons in the year 2000 to 200.000 tons, provided for 2012; the production is estimated to increase with more than 300.000 tons per annum in the next five years. Up to now, other countries to hold such deposits could not compete with China regarding the price. There are REE deposits worth billions of dollars both in Europe and the U.S.A, but, for the time being their exploitation would value the same.

In the year 2006, the extraction prices for some REE were the following: cerium – 40 US dollars/kg, lanthanum - 30 dollars/kg, ytterbium - 400 dollar/kg, yttrium – 50 dollars/kg, scandium - 70 dollars/kg. Reiterating their strategic size, through their multiple uses, often in high technology areas, the REE are subject to restricted information coming from the states, so that the macroeconomic statistics regarding this issue remain quite defective. The oxides world deposits to contain rare earths were estimated by the end of 2010, by USGS Minerals (USA) at approx. 110 millions of tons, out of which China held 50 percent; the Commonwealth of the Independent States - 17 percent; the USA - 12 percent and India – 3 percent[1]. We reckon that the American estimates are not among the best posted.

The industrial applications based on REE are performed at very high purity levels, up to 99,9999%, for the so called «phosphor» products, that stand for the REE based illuminating bulbs industry. On the other hand, the raw mining product is a mixture of 17 rare earths, called « mismetal » - « mixture of metals » in German. In order to achieve such a level of purification, it is necessary to perform a large number of operations so that the separation of these elements is obtained first. Each decomposing job involves waste products as highly polluting as the radioactivity is associated to the REE concentrates.

Similarly to the USA, China, obviously, states a lower estimation – showing that it only holds 30 percent of the world deposits, although

[1] According to USGS Minerals, 2011, *Rare Earths*

recognizing that in the present moment it provides 90% of the world industry needs, by even using technologies for recycling the rare earths contained by the electronic waste[2]. China's world production of the oxides to contain rare earths rose to approximately 130.000 tons in 2010, thus securing the country's world monopoly in this field; India, the second largest world producer states that it only extracts 3.000 tons, while the production of the Commonwealth Independent States, the USA and the other minor states – which nevertheless cumulate a fifth of the world deposits – is not reported[3].

In mid-2010, with this situation being continued at least 4 more years, by 2014 – until the opening of new mining sites on other continents: North America, Australia, Asia etc. - China was producing approx. 97 percent of the rare earths consumed around the world. On a global level, the demand for the so called critical minerals grows from year to year, and their lack of supply could result in a crash of the XXI century technology.

The increase of the Russian, Indian or Brazilian REE production, the increase of the Australian and US deposits could lead to the production of approx. 50.000 tons of rare earths until 2014. The world demand should double and reach 180.000 tons by 2014. However, all these depend on the Chinese « tap » regarding the rare earth elements. "The supply and demand will become scarce between 2012 and 2014", predicts the Australian expert Dudley Kingsnorth, who also adds "If the US and Australian projects are delayed, then we are talking trouble".

2.1. Extraction methods

No technological development of the rare earth elements would have been possible without elaborated decomposing techniques, adapted to chemical properties of the elements to be isolated. The fractional crystallizations used at the beginning of the 20th century, then the methods used for the changing ions roots granted access to the different layers of rare earth elements having satisfactory purities to have accompanied the first industrial applications (electric bulbs, lighter stones, different metallurgical and stone applications).

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[2] Chen Deming, *La Chine etudie le recyclage et la substitution des terres rarea,* sur le Quotidien du peuple, http://www.nature.com/ngeo/journal/ vaop/ncurrent/full/ ngeo1185.html, visited on the 18th of July 2012

[3] Ditto, USGS Minerals, 2011

The markets' exigency regarding the quality and the quantity always justified the implementation of the solvent extraction methods. These allowed the industrial production of the oxides or salts out of rare earths, with higher and higher purities (up to 99,99%), which are indispensable for optics related applications.

The lanthanides with small atomic number, i.e. «lighter ones », can be found essentially in the monazite minerals ($LnPO_4$); the lanthanides with big atomic number are especially extracted from gadolinite.

Promethium, which only has radioactive isotopes, was separated from the products resulted from uranium 235 fission. As the physical and chemical properties are very close, their separation is difficult; it is mainly performed through fractional crystallization, ions exchange and solvent extraction. The metals are obtained either by basic chlorides electrolysis or by the reduction of chlorides or anhydrous fluorides, by means of sodium – for light lanthanides or magnesium – for heavy lanthanides. These are subsequently purified through distillation.

No technological development of the rare earths separation methods would have been possible without the complex separation technologies that are adjusted according to the chemical properties of the elements to be separated.

2.2. The fall of the American production

For the last 20 years of the 30 in which it became a matter of great importance to the economy, the REE area has been really troubled. (See Chart 3 of the Annexes). Until 1990, the USA used to be the world leader. Part of the production was exported to Japan, Brazil and Canada. Then, in 1995, though a wise policy in its way of development - China becomes number one in the world's top producers.[4] During 1999-2000 the US was already importing more than 90% of the necessary REE, directly or indirectly from China[5]. The USA regression in the rare earths extraction field can be explained by the fact that the great American enterprises in the area ceased the extractions due to economic reasons (they could find the same product on the international market, provided by China at dumping prices). Then, for

[4] Custers Raf, *Terres rares, enjeu de développement,* on web site http://www.alliancesud.ch/fr/documentation/dossiers/matieres-premieres/terres-rares, visited on July 28th 2012, 14:51

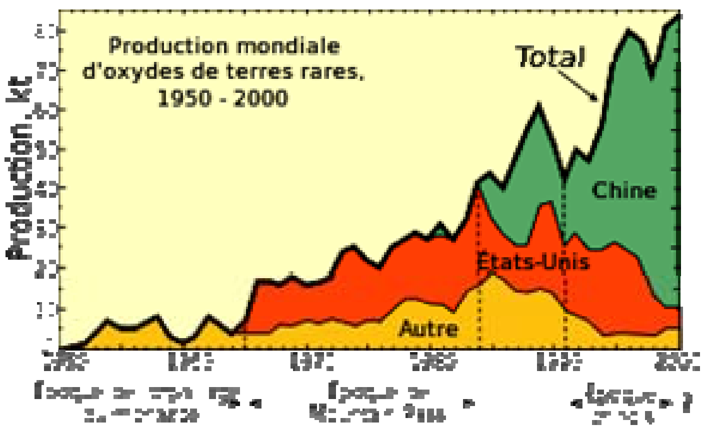
[5] ***, *Rare Earth Elements. Critical Resources for High Technology*, USGS Fact Sheet 087-02, 2002

reasons of costs increase and under the pressure of firm human and environmental health protection, America's number one in the area, Molycorp, began to have issues related to the discharge of waters coming from the Mountain Pass mine, in California, and closed the treatment plant. The mine remained under conservation, and Molycorp proceeded with the sale of REE stock-pile.[6]

In 1990, the US Geological Service assessed that the world deposits comprised 62 million tons. Out of this volume, minable by means of techniques of that time, 48 million tons, i.e. 78% of the total could be found in China, and the remaining 22% in market economy countries. During 1995 and 2000, the world deposits were estimated to 100 million tons, but the Chinese percentage has shrunk to 43. Nowadays, China still holds 36% of the REE world's deposits, which proves that China has exploited its established deposits and didn't explore and develop these deposits furthermore. The West itself started creating rare earths stock-piles imported from China. According to Chinese expert Xu Giangxian, South Korea and Japan hold enough rare earths reserves as to cover their consumption necessities for 20 years from now; 20% of the Japan supplies come from China's black market.[7].

2.3. Chinese production hegemony

Global REE production between 1950 - 2000



Source: Wikipedia, visited on July 18th 2012, 6:52

[6] James B. Hedrick, *Rare Earths*. USGS Minerals Yearsbook, 2004, selective
[7] ***, *Chinese expert calls for immediate stockpiling*, Metal Pages, 2 November 2009

Until 1948, most of the REE were sourced from sand deposits in India and Brazil. Through the 1950s, South Africa took the status as the worlds' rare earth elements source, after large veins of REE were discovered - monazite in the locality of Steenkampskraal.

Through the last decade of the 21st century and the first decade of this century, the demand of REE has constantly increased whereas the prices remained low due to Chinese production expansion and exports. In the beginning of the 2000s, the Indian and Brazilian mines were producing most of the world's rare earths headings, but they were gradually outclassed by the Chinese production, which, by 2010, was providing 95% of the rare earths world supply[8]. The USA and Australia hold strategic reserves (12% and 3% respectively, of the global deposits), yet they stopped their exploitation due to China's[9]competitive prices and concerns on environmental pollution.[10].

For the Western countries, which try to improve their supply, such situation has become even of greater concern as on September 1, 2009, China announced plans to reduce its export quota to 35,000 tons per year starting 2010, from a total production of 130.000 tons. The argument to justify such decision refers to the wish to conserve scarce resources and protect the environment, which has become affected by the exploitation of the rare earths deposits.

In 2006 the Chinese Ministry of Commerce stated that the country's REE deposits reduced by 37% between 1996 and 2003[11]. Actually, the measures China announced in September 1, 2009 were set in order to meet the growing internal demand. During 2006-2010, China reduced its export quota by 5-10% per year and the production was slightly limited in order to protect the precious metals from over-exploitation in 15 years[12]. Nevertheless, in the previous decade, China took over the REE extraction world industry.

All of the world's REE range comes from Chinese rare earths sources, such as Bayan Obo great deposits, in the District of Bayiun, Province of Inner Mongolia. Rare earths can also be found on the Tibetan Plateau. The command of the Chinese army over the High Plateau of

[8] cf. D'Arcy Doran, *La Chine réduit son offre de terres rares pour protéger ses intérêts*, AFP sur Google News, le 24 octobre 2010

[9] lower due to cheap Chinese labour

[10] ***, *Pékin joue de l'arme des terres rares*, în Le Figaro, 25 octobre 2010

[11] pe site-ul www.GreatWesternMineralsGroup.html*, vizitat pe 19 iulie 2012, orele 5,52*

[12] ***, *La Chine reduit ses exportations de terres rares pour debout 2011*, în Le Monde, 29th of September 2009

Tibet carries immense farming exploitations and large cattle growing farms, sells wood, builds roads and railways, prospects and exploits mineral deposits: gold, uranium, nonferrous metals, rare metals. Illegal mines are spread in the Chinese Plain, and their exploitation often leads to waters and environmental pollution.

According to Gregoire Macqueron, China supplies 96% (other researchers speak about 97%) of the global production resulted from these raw materials, which it controls, against some harsh reactions of the industrialized countries (see next chapter), in a strict manner (by means of export quotas and taxes) in order to protect its own industry[13].

In the January 2011 edition, Beijing Review wrote: « we have become world leaders because we tolerate a quick and expensive exploitation »[14]. From 1978 to 1989, the Chinese REE production increased by 40% per year[15]. In the mining field of Bayan Obo, the state's enterprise Baotou Iron & Steel en Baotou Rare Earths controls the largest rare earths mine in the world; it comprises a highly performing mining and raw metals treatment plans. However, alongside state's enterprises, hundreds of private companies proliferated; in Jiangxi there were 1.035 at a certain time. Such operations source a true nightmare on the environment, and the lack of efficient control from the Chinese State allowed the Western consumers to buy rare earths at very low prices.

After 2006, the Chinese authorities imposed export quota for the rare earth elements, so that the gradually increased exports are not exceeded (see chart 4, in Annexes). Several parameters lead to such:

1. REE shall, preferably, feed the Chinese Industry, which is constantly growing;
2. The mining sector and the heavy industry are matters to be subjected to radical drainage. In 2010, nearly 1.600 mines considered as being dangerous, expensive and technologically outdated, have been closed. Approximately 100 such mines and

[13] Grégoire Macqueron, *Des terres rares en abondance pour les technologies vertes?,* on we bsite www.Futura-Science.com, visited on 19th of July 2012, 8 :15

[14] "It was the country's tolerance for quick and dirty extraction that made it the global leader". *Rare earth even rarer,* Beijing Review, 21 janvier 2011

[15] Hurst, Cindy, *China's Rare Earth Elements Industry: What Can the West Learn?*, Institute for the Analysis of Global Security, Washington, mars 2010

illegal antimony furnaces[16] could be found in the Hunan Province. The rare earths extraction mines have also become subject to this process;

3. The REE sector has been reduced to around 5 or 6 states enterprises. By 2015, the number of enterprises to extract REE shall reduce from 90 to 25[17]. Thus, China intends to end the anarchic despoliation of its deposits that would have been depleted in 35 years, had the extractions continued in such manner[18].

China is expecting a better price for the REE on the world market. It intends to return to the situation that prevailed during 1998-2005, when the REE exports multiplied by 10, and the prices dropped by 36%[19]. *Per se*, today's China is producing just about the entire REE oxides quantity used worldwide - 139.000 tons in 2008 and over 200.000 de tons in 2009. Keeping this trend, in 2010, China was producing a quarter billion tons of rare earths, intensely required and used in the top technology worldwide!

The mines and the surrounding regions falling under the heading of Baiyan Obo are regarded as being of national strategic importance and are constantly surveyed by police squads. The ore is conveyed from a 200 m depth, where the mining crater is, by Terex trucks, the largest in China, 2 storied building high, which can transport up to 168 tons of REE containing rock at a time; four shifts of drivers ensure the operation of trucks 24/7.

The REE exploitation of Bayan Obo lead to total annihilation of the local environment and ecosystem, and transformed the area in an industrial area which provides an apocalyptical view. The refineries can be found 150 km from Bayan Obo, in the low valleys, north-west of the mining city, in the industrial outskirts of the city of Baotou, in different stages of functioning. They are surrounded by partially frozen 10 km wide lakes, impregnated with the red trails of the acids. The surrounding area is marked for many years from now by the refineries poisonous wastes. The soil is filled with ditches and trenches. Some of the villages were relocated due to intense pollution.

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[16] Antimony is used, among others, fro clothes fireproofing, increasing heir fire resistance. China produces approx. 90% of the world production; after***, *Antimony on a high as Beijing goes green*, Financial Times, 15 septembre 2010

[17] ***, *China's rare earth campaign targets environmental protection*, Xinhua Insight, 16 septembre 2010

[18] Xu Guangxian et al., *An Emergency Call for the Protection of Thorium and Rare Earth Resources at Baiyun Erbo and the Prevention of Radioactive Contamination of the Yellow River and Baotou,* quoted by Cindy Hurst

[19] cf. Beijing Review, 21 janvier 2011

At an isolated processing factory in the Chinese province Inner Mongolia, called He Jiao Mu Qu, approx. 50 km south of Bayan Obo, the sulphuric acid is boiling, erupting in the crevasses. The largest discharge lake of Baogang, with a surface of 11 sq m, is full of toxic waste. The toxic air, filled with sulphur, stings the eyes and burns the lungs, and the workers' clothes are full of acid burns. At the end of some centrifugal steel pipes, several furnaces boil some kind of yellowish lava. Under such inhuman circumstances the wage of a single worker is of 1.600 Chinese Yuan per month, the equivalent of approx. 220 US dollars. The Bayan Obo ecological decimation caused by the extraction of REE is of epic proportions.

Currently, in China, the products based on REE are being used in more than 30 industrial areas, and their development and use has become the main growing pole, of the Chinese and global rare earths.

The games of WTO

The change of the Chinese policy regarding its massive REE exports started to alarm Western countries, which showed concern in respect of their supply with such strategic materials. In September 2010, a double hit occurs:

– Japan arrests a Chinese fishing ship, which apparently was fishing in its territorial waters, but it soon finds out that the its REE shipments are blocked in the harbors of China. Next, Japan accuses China to have deliberately interrupted its REE exports. The result of the incident led to the impression that China used its monopoly in order to punish a competitor;
– At the same time, in the USA, the United Steelworkers (USW) files a formal petition against China, in order to stop or reduce competition in the green economy[20]. The petition consists in a 5.800 pages file. In the argument of the petition, USW denounced the Chinese restrictions regarding access to these critical materials; pursuant to USW petition, China undertook a range of measures which were not authorized by the World Trade Organization (WTO). Furthermore, the American Union added that the export restrictions lead to price increase outside China, and urge enterprises to relocate production in China, which would strip USA of the rare earths based industries. The US Government considered the USW petition but no immediate formal complaint was filed to the WTO. By 2009, The USA, EU and

[20] ***, *USW Files Trade Case to Preserve Clean, Green Manufacturing Jobs in America, United Steelworkers,* communiqué de presse, 9 septembre 2010. site Internet de l'envoyé commercial du gouvernement américain où l'on trouvera un résumé. Voir: http://www.ustr.gov/about-us/press-...

Mexico have filed a similar complaint against China because the latter had limited its exports to a dozen of minerals, from bauxite to zinc.

In return, China stated its right to use its own natural resource as deemed convenient and showed that it didn't impose export quota for the parts manufactured in China[21]. Chinese sources stress the westerners' interests for as low as possible REE oxides prices and add that, China is doing the opposite of what the USA has done – i.e. it is assuming the highly polluting mines.[22].

Other American and foreign bodies also stressed the dependency on the Chinese R. We are speaking about the US Departments of Defense and Energy, Japanese Government, the European institutions and the German industry. Yet, the United Steelworkers petition was the most combative in this controversy[23].

Actually, in the rare earth elements policy and economy, two great directions were developed:

1. The industry of REE outside China became more dynamic. Molycorp, the strongest US company in the area, reopened the Mountain Pass mine, by means of the 275 million Euros received from the US Government. In Australia, Lynas enterprise reopened the Mount Weld mine.
2. Today, at least 20 exploitation and production projects are ongoing. The financial institutions already begin « to see » the opportunity to make profit, investing in such projects. In the fall of 2010, for example, the value of the stock market index of the rare earth elements enterprises increased by 35%. At the same time, the large consumers are developing alternative techniques to reduce the dependency on the REE. The manufacturer Toyota is making these attempts by using a prototype for the engine without permanent magnets and Hitachi has already developed a technology to recover the rare elements from hard disks. At diplomatic level, the Chinese president, Hu Jintao, while on a visit to the USA, reassured the Americans that « the practical cooperation » will continue to develop to benefit of both sides[24].

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[21] ***, *China does not have monopoly on rare earth*, Caijing Guojia Zhoukan, 31 octobre 2010

[22] ***, *China defends its policy on rare earth export control*, Communiquee gov., 29 août 2010

[23] Such point of view was considered more chauvinistic than the one of the USA Chamber of Commerce. The following phare is a relevant example: "The USW believes that the nation that leads the clean energy economy will lead the global economy". Apud *United Steelworkers' Section 301 Petition Demonstrates China's Green Technology Practices Violate WTO Rules*, USW communiqué, 9 septembre 2010

[24] ***, *China leader answer questions on currency, relations with US*, Wall Street Journal, 17 janvier 2011

3. In Europe, the point adopted by the Bundesverband der Deutschen Industrie (BDI), which groups the German federations of employers is significant. Following the third BDI congress regarding the raw materials supply security, (Rohstoffsicherheit), from October 2010, its President Hans-Peter Keitel stated: « We are not at war with anybody, but China is causing the most issues and its measures are against the WTO regulations. Particularly, we are purchasing 97% of China's rare earth elements». The solution proposed by Hans-Peter Keitel was to grant free access to these natural resources.[25].

The free access that the German industry claims for itself is not granted through reciprocity to the Chinese enterprises in Eastern Europe and Central Asia that have become the new German «hinterland» (area of influence)[26].

The Head of the German federation of employers BDI stressed the fact that Germany's industry is based on a supply strategy established in 2008 by the European Commission and known as the "Raw Materials Initiative"; the work documents of this strategy identify 14 critical minerals obtained from rare earth elements. On February 2nd 2011, this strategy and an adherent action plan were made public by the European Commission with the purpose of supplying the EU industry with critical minerals.[27]. The Commission does not exclude the appeal to commercial reprisals, if necessary.

[25] Hans-Peter Keitel, *Rede. Rohstoffsicherheit für Deutschland und Europa*, 26 octobre 2010

[26] A possible model for such a strategy would be the natural gas pipes business which the Federal Republic agreed with the former Soviet Union in the seventies, Dans: *Position Paper. Chinese Activities in Eastern Europe. Success through market-aggressive financing offers*, Ost-Ausschuss des Deutschen Wirtschaft, BDI, octobre 2010

[27] Rede von Bundeskanzlerin *Dr. Angela Merkel auf der Jahresmitglieder-versammlung des Ost-Ausschusses des Dertschen Wirtschaft*, Berlijn, 14 oktober 2010

Chapter 3
REE REPARTITION

After separation by technological processes, some quite complicated, oxides of the 17 minerals contained in chapter 1 are primarily used to obtain high-tech products, as well as some green technologies.

After the volume of deposits, the main concentrates of minerals containing REE are found, as we pointed out in chapter 2 of our work, in China (in Inner Mongolia province) in the U.S.A, Australia, India, the former USSR. Some sources estimate that 47 percent of the REE world reserves are found in China. The remaining 53 percent of these reserves are found almost everywhere: in 2002, the mine from Mountain Pass (California, U.S.A.) has closed its doors (see Chapter 2); equally the strongest mine in Australia. Then, in 2012, both mines were reopened; there are still active mines in Central Asia and South Africa. Geological studies have identified REE deposits in the island of Greenland and even in the European shelf. The problem is that putting in place an exploitation takes a long time. It takes 5 to 10 years to do research and gather the necessary permits.

Researchers are working to find alternative solutions to enable companies to obtain products of the same level; it was advanced in this sense towards recycling products containing REE, to reuse these REE. And if the price of rare metal separation from deposits will increase, it will be more profitable for them to be recycled.

3.1. The main deposits. China

REE industry began to be developed in China in 1950. The Chinese production gradually started in 1985. Exporting at very low prices, the Chinese eliminate any Western competition: their monopoly installed bit by bit.

In the motto of our work there are the prophetic words uttered in 1992, by Deng Xiaoping, the leader of China at the time. His comment was the basis of an extensive program of development and exploitation of REE vast reserves of China, reserves estimated in 2012 to 57 percent of the global total. After seven years of Deng's remark, his successor, Jiang Zemin urged China to move forward: "Improve the development and use of rare elements," he urged, "and change the advantage offered by resources into economic superiority." Then, Beijing has invested millions of dollars in the basic researches and applied in the REE field and carried out researches in two state laboratories, where hundreds of scientists work, dedicated exclusively to this field. The only two magazines in the world for rare elements are in Chinese.

In 2012, after 60 years of development and construction in the REE field, although the use of these resources is not in compliance with environmental standards, China is the largest country possessing REE deposits, the largest producer, consumer and exporter. Bayan Obo mines (Inner Mongolia, an autonomous province of China), located on the border with Mongolia, has the largest REE deposits in the world, but combined with iron deposits. Bayan Obo represents for REE what it meant Saudi Arabia for oil. Bayan Obo deposits contained two-thirds of the total REE known on the planet in mid-2010.

Bayan Obo mines have tripled in the last 10 years the REE production to reach 125,000 tons in 2010. Local peasants, land holders containing REE deposits sold to the Chinese government the land in question at very high prices. The two major mines in China that extract REE are controlled by the mining giant Baotou Steel Rare Earth, a company with public capital. Operating costs are low because Chinese labour is very cheap: the miners do not earn more than 150 euros per month. The techniques used in separation processes are controversial, since the toxic chemicals are used for minerals refining processes.[1]

Baotou is a city with rank of municipality, capital of prefecture, situated on the northern bank of the Yellow River, located at 160 km to the west of Hohhot, the capital of Inner Mongolia[2]. Baotou is the largest city located on the north side of the country. The region was colonized by Chinese and served as a garrison during the Tang Dynasty (618-907), then being occupied by the Mongol tribes. In 1730 it was still a hamlet, which was consolidated as a frontier town during the Qing Dynasty (1644-1912). Baotou then gradually developed as a

[1] acc. Stéphane Pambrun, *A Pékin, on ne badine pas avec ce nouvel Eldorado,* on the website www.novethic.com, visited on May 4, 2010

[2] after Encyclopaedia Britannica Online, website visited on September 19, 2010

city of the market economy. In 1923 it was linked through railway of Beijing and since 1925 it has the status of administrative capital of county. Throughout the twentieth century it grew rapidly, becoming an important commercial centre for trade in Mongolia and north-western China, controlling also the marketing area, including most part of what is now Ningxia Autonomous Region, as well as Gansu and Qinghai provinces. The area from the north of Huang El was colonized by the Chinese in the late nineteenth century and Baotou has become the main trading centre for the Chinese community. The city grew rapidly, and during the Japanese occupation (1937-1945) it was a centre of the autonomous government of Mengjiang. The Japanese began to develop light industry in the city and, also there were discovered nearby rich deposits of coal and other minerals.

After the establishment of popular power in 1949, Baotou has been completely transformed. Its rail link with Beijing, which was destroyed during the civil war in China, was restored in 1953, and the railway was doubled in the late 1950s. Another railway was built to the southwest of El Huang, to the city Lanzhou in Gansu, allowing rail link with central and southern China, or the city Urumqi, the capital of the Uighur autonomous republic from the northwest of the country.

Baotou becomes an important centre for steel manufacturing, based on the iron ore discovered on north, in Bayan Obo, a town to which it was linked on the railway; to all these contributed the coking coal found in Shiguai in east, near Daqing Mountains, and then REE deposits found also in the area. Steel complex in Baotou began work in 1961, becoming fully operational only in the late '60s.

Subsequent economic growth of Baotou was phenomenal, the municipal area is expanded to include coal mines in the east and iron and complex ore in the west. The city has emerged as a major industrial base not only for Inner Mongolia and northern China, but for the whole country. Industrial development continued. Another railway line, completed in 1989, connects Baotou with the north of the country and the province Dongsheng, rich in coal. Since 1992, high technology is introduced widely in the industrial park of the city; here there are produced machinery, chemicals and electronic equipment. Baotou is linked by Hohhot through a motorway. About 2 million Chinese live today in Baotou.

A subsidiary of Baotou Steel Corporation, Baotou Steel Rare Earth, specialized in REE processing is now developing in Baotou; there have already been approved investments of 3 million dollars. Local Government cherishes the hope to build in Baotou a world-class industrial base in the REE field and to establish a mechanism to stabilize prices in this field. The REE reserve in Bayan Obo, near Baotou, contains about 75 percent of the total REE from China. This great Asian country, of the planet, produces 97 percent of the world's REE.

China is the only country that produces almost all rare ores and has already announced its refusal to export them. Understanding the geostrategic importance of its REE deposits, China decided in early 2010 to use them only for the production obtained in its domestic market. The press news remained discreet on broadcast media, in failing attention. In an attempt to control the concern for its REE, China has authorized foreign factories to produce on its territory and participate in the operation of these mines. Probably between 2011 and 2012, Chinese domestic demand for REE will exceed the capacity of production. "This situation obliges China to ban the export and sale of REE abroad," said Jack Lifton, specialist in the field. Perhaps after 2012 China will become the first manufacturer of solar panels and wind turbines in the world, two intensive industries of REE.

China now controls the major part of global production of rare metals: 95 per cent of the total volume of production of oxides from REE, 87 percent of the production of antimony and 84 percent of the production of tungsten. Europe and U.S. are concerned about the limited access that they have at the vital minerals for the advanced technologies[3]. A European Commission report expresses concern about a possible shortage of the 15 lanthanides, rated "critical metals" for industry. China has become itself a major consumer of rare and critical metals.

Given the strategic importance of the area, workers at the Air Traffic Management Bureau of Hohhot observed on September 11, 2010, at around 20 p.m. (local time), an unidentified flying object (UFO)[4], at 40 kilometres east of Baotou, in Inner Mongolia Autonomous Region. Landing three aircraft belonging to some flights from Beijing and Shanghai to Baotou were delayed, and the aircraft were forced to fly in circles while waiting to land; Air China flight 1107, from Beijing to Baotou landed on the Erdos Airport and Juneyao Airlines flight 1137 from Shanghai to Baotou landed on the Taiyuan Airport. Only after two hours, Baotou airport received a notice concerning the resumption of normal operations.

[3] Simona Haiduc, *China controlează azi cea mai mare parte din producția globală de metale rare*, in Financial, June 22, 2010, p.10

[4] quote from People's Daily Online, 2010 September 13

In August 2010, companies Baotou Steel Rare Earth High-Tech Co and Jiangxi Copper Corp have proposed to launch a unified pricing mechanism at national level on light REE - measure, which had to allow China to play a more important role in international markets of this very precious mining resource.

China supplies more plus than 95% of REE oxides in the world and has more than half of the world reserves. Baotou Steel Rare Earth provides alone 46% from the supply of REE in the world market. Approximately 100 small Chinese factories produce REE in Baotou throwing waste in the Yellow River. We are facing a paradox of the current technique, between the use of REE for the reusable energies field and cleaner production processes.

Here's what experts say: "China's goal is to create new jobs and produce goods based on REE", estimates Jack Lifton, independent analyst specialized on this topic in the United States, who continues: "We have to start to produce these rare metals in the United States, as we did another time. If not, China will be the only country to produce products having in composition REE in 2015."[5] "The Chinese government hopes that the restrictions imposed will lead to the transfer in China of some technologies related to REE," said Ren Xianfang, economist at Beijing of IHS Global Insight.

Alarm signals crossed on red in 2010 when analysts were faced with authorities' attention on these raw materials. The Chinese government was even considering the ban to export REE as well as closure of mines. If such rules were adopted, foreign enterprises were deprived of these metals widely used today in high technologies, including for military rockets production. "It's a crucial time," said also the Australian Dudley Kingsnorth, consultant in this field, who also added "In future years, import quotas for REE will be reduced and increasingly fewer countries will depend on resources in China; on the other hand, increasingly more companies have to relocate to China to ensure their supplying."

At the end of September 2010, paradoxically, China announced its preparedness to resume its exports of rare metals to Japan[6], after the embargo imposed in the diplomatic crisis occurred between the two countries. Katsuyuki Matsuo, the chairman of Nippon Company Kan

[5] Allison Jackson, *Les "terres rares" Trésor convoité de la Chine*, on the website www. aujourdhuilachine.com/actualites-chine-les-terres-rares-tresor-convoite-de-la-chine-12900.asp?1=1, visited on December 1, 2009, at 10.56 a.m.

[6] ***, *La Chine reprend ses livraisons de terres rares vers Japon*, in Le Monde, September 29, 2010

Material specialized in rare metals trade, confirmed that Chinese customs resumed after only a week of disruption, on September 28, 2010, registration procedures of exports of these precious materials for the Nippon archipelago. Another Japanese importer, speaking on condition of anonymity, explained that the situation is different "*from one port to another, because there was no official embargo. We are more confronted with administrative harassing.*" Nippon State Secretary for economic and fiscal policy, Banri Kaieda, confirm that Beijing has blocked its sales of REE to archipelago, stressing that "*it is important to cease as soon as possible this totally abnormal action.*" He also stressed the need for Japan to develop its "*alternative*" supplying ways to face this kind of problems in the future.

In recent years, China has achieved a quota to export of REE, amounts which reduced them year by year, banning the export of REE in 2012. As stated above, the annual production of REE is about 125,000 tons per year, of which 97 per cent belong to China. This monopolistic control of production is largely tied by the deposit Baiyan Obo, located near the city Baotou in the north of China, in the so-called region of Inner Mongolia.

The ban of REE Chinese exports has several explanations: official target communicated is the intention of the Chinese authorities to bring together manufacturers to control better the quantities of waste they produce, which will lead to closure of small producers mines, the most polluting, so in a short period of time to reduce production and increase demand for REE in the world market. The industrialized countries have already been "invited" to relocate in China their manufactured production based on REE.

Chinese premier Wen Jiabao highlighted in a forum with American business men, that "an iPod is sold with 299 dollars USA and in the manufacturing chain, China receives only 6 dollars USA for it. Since 2008, China consumes more than half of its total production of rare elements and on the black market of these chemicals a big part of them is transacted.

China understood the strategic interest for these metals since the 80s of the last century. In that era, the countries relied on free exchange to ensure access easier to resources. Without taking too much into account the environmental constraints, China - the holder of the largest REE world reserves - has increased since then, year by year the production, which allowed it to replace USA on the first place in the top of the world producers.

Then, after 2005, with other economic interests, China has limited permanently its REE exports[7]: between 2005-2011, they decreased from 60,000 tons to 30,000 tons of REE exported by year when global demand passed from 46000 to 50000 tons per year. The price of these critical minerals increased in this period of time even 1,000 times, even if they were or are used in a small amount in the finished products, which until 2012 had no visible repercussions manifested by higher prices of respective products to the consumers. Rising prices of REE only affected intermediate production.

According to an initial complaint lodged to WTO in late 2009, by the European Union, U.S.A. and Mexico, WTO specifically asked China to clarify its export quotas imposed for its REE[8]. It is known that since 2010, China provides a quasi-monopoly of REE production over the world. Moreover, China consumed more than 50 percent of its own production. Other REE consuming countries are Japan, U.S.A. and developed countries within the European Union (Germany, France, Italy, and U.K). In 2010-2011, after the drastic reduction in REE Chinese exports and even the ban of such exports in 2012, some of the above mentioned countries have resumed their activity extraction despite the consequences of the environmental pollution and to counter reduced shares of production announced by China.

Chinese export quotas have been reduced drastically, practically halved to about 30,000 tons since 2011. Then, the Chinese government gave assurances that the level for 2012 will be the same with the one in 2011, later announcing the embargo on exports of this kind. In March 2011, U.S.A., European Union and Japan have filed a complaint more to WTO, due to limitations on export imposed by China for its REE; due to monopoly position of Chinese extractive industry of oxides of REE, China has been convicted in this file at the end of 2011.

After criticism of its trading partners for the restrictions imposed on export of these minerals essential for high-tech[9], the Chinese government announced in mid-May 2012, additional export quotas of REE; thus producing Chinese enterprises can export supplementary about 11,000 tons of REE in 2012, i.e. a total amount of 21,226 tons,

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[7] Dominique Albertini, *Les terres rares, un élément majeur de la puissance chinoise*, in Liberation, March 14, 2010

[8] ***, Matieres premieres: defaite chinoise devant l'OMC, in La Tribune, 28 December 2009

[9] ***, *La Chine autorise des quotas supplémentaires d'exportation de terres rares*, in Liberation, May 17, 2012

according to a press release from the Ministry of Commerce of this country. The Chinese government also announced shortly before the embargo on REE exports...

Economic observers agree that in order to ensure its control of these strategic minerals, Pekin has developed a long-term industrial policy to limit its exports in order to "barge the big geopolitical game world."[10] However, the overall strategy is based on the game of alliances between Chinese producers and the ones who process minerals based on REE in the West. Today, the issue of restriction on the use of REE worries defence industries in the developed countries of the planet. Growth of China's military power reveals the strategic error that Westerners committed.

In the race to build hybrid cars and wind turbines, to feed growing demand for green technology, China has a clear advantage - has the world's largest reserves of REE and thus dominates global production.[11] Wind turbines Xinjiang Goldwind Science & Technology brand are hybrid cars produced with funding of the American billionaire Warren Buffett.

China reduced its REE exports systematically since 2005, applying quotas and taxes, saying that limiting exports is based on its needs to supplement domestic production of goods based on REE and to develop clean energy sectors and high-tech. In 2010, export quotas on REE were reduced again by 40 percent. China's trading partners have responded to the new export quotas reductions, noting that Chinese politicians want to control the REE world market. In order not to face risks in supplying, some foreign companies in the REE field have decided to move their production lines in China.

Lax environmental standards and cheap labour have allowed China to sell long time at export the REE production at low prices, of dumping (below market price). Lower prices with whom China sold REE undermined global production, which led to the closure of REE mines in many countries of the world. Baotou Steel Rare Earth Hi-Tech Co. increased its REE reserves with about 200,000 tons, which allowed it then to determine world prices.

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[10] ***, *Terres rares, un enjeu stratégique,* in Le Monde Diplomatique, March 15, 2012

[11] Leonora Walet, *Asia Green Investment Correspondent, Rare earths crucial in drive for green gadgets,* correspondence Reuters from Hong Kong, August 12, 2010

American China Company BYD bought lithium deposits reserves in the Sichuan area, Chinese province known for its rich reserves of lithium and other materials. In parallel, a sister company developed by the Toyota automobile company has ensured a contract to supply lithium from Argentina while Toshiba Corp, another rival Japanese company created a joint venture with state-owned company Kazatomprom, from Kazakhstan. This allowed designers from Toyota to successfully launch the hybrid car Prius that works on gasoline and electricity stored in batteries, which is sold very well, to Nissan manufacturers - to launch the electric car Leaf, and to those from General Motors to design, in their turn, the hybrid model Chevy Volt. But only one accumulator (battery) from the endowment Prius uses 10-15 kg of lanthanum.

On June 6, 2012, BBC Mundo said under the title "China's economy is deflating?": "Some indicators are beginning to point to an economic downturn in the Asian country with a strong decrease in electricity demand and industrial production, as well as factories efficiency and retail sales. China suffers for months because of the "cold wind" blowing from Europe – its higher export market, even higher than that of the United States. The country's manufacturing sector has contracted for six months, mainly because of the weak export demand, according to a recent study ... Many enterprises have financed the import of raw materials such as copper, iron and aluminum for the construction industry. Supplies of unused copper that accumulates in warehouses of China have become so large that there is hardly space to keep the surplus. This may be only a temporary problem in short term, but it could be the beginning of the end of the housing boom, where there were built much more apartments than the country actually needs. There are ghost towns completely built. It seems that many of these empty floors were purchased by enterprises and Chinese families as an investment more attractive than depositing money in a low-interest bank account. Growth rate in China fell under the magic number of 10% when the West fell into the deepest recession where it is found from the World War II. For example, the Asian giant has built from scratch the largest high-speed rail network in the world, five times the volume of French high-speed network.

China is in the middle of a delicate transition, with a new generation of leaders, approaching to power, something that happens only once at 10 years. There is a political battle boiling, evidenced by the dismissal of the ostentatious governor of Chongqing, Bo Xilai. Many party members have benefited from the housing boom and credit in the past three years. If this peak is over, they will not want to be part of the inevitable losers. How this battle will take place, especially if China is facing protests of the unemployed workers out in the streets, is unknown to everyone."

Here's how Fidel Castro commented this news[12]: "I am far from sharing this Yankee grim scenario about the destiny of China, and I wonder if it can be ignored that *China has the largest REE reserves in the world* (subl. ns.) and enormous volumes of shale gas that will enable it to exercise its power over global energy production when the power to lie and obey will cease to exist. It is already too much."

3.2. Position of other countries

Bolivia has large deposits of REE, Canadians already explore in the south of the country in search of REE. Australia and Brazil have recently identified such deposits; but no new mining operation may begin sooner than 2014. Issues are not given by the rarity of REE, but by the difficulty of their extraction.

Afghanistan

In January of 1984, shortly after the outbreak of hostilities in the "war with the Soviets" the director of Afghan Department of Geology publishes a report that the subsoil of the country had a large variety of mineral resources, including iron, chrome, gold, silver, sulphur, talc, magnesium, marble and lapis lazuli. It was only a superficial estimate, Afghan geologists not having at the time the performing equipment with which to evaluate all the minerals in the subsoil or at least the size of deposits in question. Information provided by Afghan geologists had already reached the ears of the Soviets, who even before the beginning of their presence in Afghanistan knew that this arid country hides also other riches than the huge deposits of natural gas, which the Kremlin was aware since 1957, when Russian geologists were investigating the natural gas reserves near the river Amu Daria.

Afghan government at that time was a puppet supported by the former Soviet Union: therefore, the authorities in Kabul were preparing to develop and exploit mineral resources based on technology of extraction and processing ex-Soviet, together with the engineers trained in Moscow; obviously the former USSR intended to keep the lion's share for itself. Another treasure long sought and the eyes of ex-

[12] ***, *Reflecțiile Comandantului Fidel,* Embassy of Cuba in Romania, June 9, 2012

Soviet were aching after it, consisted in Afghan uranium reserves very popular throughout the world since they provided the raw material for nuclear weapons whose development was at its peak to mid-80s of the last century. Over the Soviet-Afghan plans however dust spread out after the defeat of the former URSS by mujahideen, event concluded with Russian withdrawal from Afghanistan in 1989.

In 2004, American geologists, sent to Afghanistan as part of a team rebuilding, they found a number of strange maps in the warehouse of Afghan Geological Survey Office in Kabul. At first evaluation, the maps presented new data on mineral deposits of the country. U.S. team learned later that the data were collected by Russian mining experts detached here during the Soviet occupation of Afghanistan. In the rush of the withdrawal in 1989, all maps and materials made by Russian were abandoned.

During the chaos of the '90s, when Afghanistan was troubled by endless civil wars and iron regime of the Taliban, a small group of Afghan geologists managed to protect maps, hiding them in their houses. Afghans geologists have returned Afghan Geological Office only after the American invasion and overthrow of the Taliban regime in 2001.[13]

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[13] "The maps were made long ago, the places were known, but the development of mining was non-existent in the 30-35 years of continuous wars," says Ahmad Hujabre, an Afghan engineer who worked in '79 in the Ministry of Mines in Afghanistan, mention made public on the website www.7126569-comoara-din-afganistan-adevaratul-motiv-al-invaziei-americane_files/index_white_980.htm, visited on September 11, 2010

Armed with the old Russian charts, the U.S. Geological Survey began performing since 2006, a number of overflights in height on Afghanistan. American scholars have used the latest equipment, based on magnetic and gravity measurements. The equipment was mounted on an aircraft type Navy Orion P-3 who flew over thus 70 percent of the country surface. The data obtained were so optimistic for Washington that, in 2007, the team of geologists returned for an even more sophisticated study, this time aboard of a British bomber aircraft, equipped with instruments that offered three-dimensional images of mineral deposits of small and big depth. It was the most detailed and advanced study on Afghan basement ever made. The results were - apparently - forgotten, because in November 2009, a special force, delegated by Pentagon with the mission to find the final data on Afghan wealth set up immediately in "the theatre of operations against terrorism".

By 2010, according to Pentagon data, the largest natural deposits investigated include *major deposits of iron and copper*. Deposits are so large that situates, theoretically, Afghanistan on the top of the states with the

In November 2009, not coincidentally, a team of specialists from Pentagon and American geologists discovered mineral deposits in Afghanistan worth about 1 trillion (a thousand billion) of dollars.[14] In early September 2010, the Minister of Mines of Afghanistan, Wahidullah Shahrani came out at the ramp with a statement which, literally overthrew the stock exchanges in London, New York and Tokyo. Afghan official said that, following repeated research, carried out by American geologists and Pentagon specialists, the deposits value of natural minerals, initially estimated at about 1 trillion dollars is actually much higher.

According to data submitted by American scholars, only lithium reserves in Afghanistan are higher than those held by Bolivia, the country considered, by 2009, the first world exporter. Similarly, the natural reserves of copper and iron are well above the original estimate. Only iron reserves in Bamyan province are higher than those

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largest reserves of copper and iron in the world. Other finds include *large deposits of niobium*, a light metal, very rare, used in producing steels with superconducting properties.

Afghanistan's *natural gas reserves* contain approximately 150 billion cubic meters. *Coal deposits* in this country sums up also the enormous turnover of over 400 million tons.

In 1983, in Khwaja Rawash Mountains, situated at north of Kabul, Soviet experts have identified one of the largest *uranium deposits* in the world. In 2009, Americans discovered further that Afghanistan also holds similar deposits of uranium in Koh Mir Daoud near Herat and Kharkiz, in Khandahar province.

More, Afghanistan also holds important *deposits of natural asbestos, gold, silver, nickel, zinc, mercury, bauxite, potassium, graphite, tourmaline, emeralds, sapphires and rubies*. Afghanistan's gold deposits are also not modest; some experts estimate that if it moves to exploit all the gold deposits in Afghanistan, the world market of gold will fall by over 50 percent in the first month of operation!!! (sic!)

But the great wealth of the Afghan subsoil consists in *iron deposits with an unprecedented purity*. At first estimation, the ferrous deposits contain about 2 billion tons of mixed hematite and magnetite, mixtures containing about 62 percent pure iron. The largest *copper deposit* in Afghanistan is 50 km north of the capital Kabul, in Aynak valley. The deposits contain over 300 million tons of ore with a copper purity of 0.7-1.5 percent.

About 80 percent of the *world reserves of lapis-lazuli*, a semi-precious stone, are yet untapped, being hidden in the Afghan basement. Before the Soviet invasion in 1979, Afghan miners extract annually about 6,000 tons of lapis-lazuli, a tiny amount compared to the bulk of deposits.

[14] ***, *Comoara din Afganistan – adevăratul motiv al invaziei americane?*, on the website www.mozilla.firefox.ro, visited on September 16, 2010

in Western Europe. Shahrani has said that U.S. data, according to which mineral reserves found would be worth "only" 1,000 billion dollars, were launched particularly, because a year ago Washington did not want to destabilize profile markets by announcing a sum of their value of about 3,000 billion dollars.

According to some U.S. officials, the new discovery has fundamentally changed the economy of Afghanistan, and the course of the unjustly war held by the U.S.A. for these resources, which are actually the property of Afghanistan. New warehouses, previously unknown, which contain huge veins of iron, copper, cobalt or gold and critical industrial metals such as lithium, are so big and include so many minerals essential to modern industry that Afghanistan could be transformed eventually in one of the most important mining centres in the world. According to an internal memo of Pentagon, Afghanistan could become "Saudi Arabia of lithium," a key material in the manufacture of batteries for laptops.[15]

The Afghan government and the president Hamid Karzai were informed about the new discovery. Although it may take several years to develop a mining industry here, the potential is so great that officials and executives in the industry believe they could attract heavy investments, even before mines are profitable, providing the possibility to create jobs that could detract from the war. "There is a stunning potential here," said Gen. David H. Petraeus, the head of U.S. Central Commandment. "There are a lot of conditions, of course, but I think there is a huge potential," he added.

United States announced that the discovery of these large deposits of minerals in Afghanistan is of such a magnitude that it could modify the Afghan economy and the course of the war waged by the Allied coalition, led by U.S.A. for so many years. The deposits contain ores of iron, cobalt and gold, as well as rare metals such as lithium, essential for the modern electronic industry.

Perhaps the most coveted "treasure in Afghanistan" is in huge lithium deposits discovered by Americans in the autumn of 2009. Alone, only lithium reserves could pull Afghanistan from the severe poverty of today and - in theory - would turn it into a richer country than the 10 eastern European countries joined in the European Union on the occasion of the wave of integration in May 2004. It is known that the

[15] quote Mihaela Stoica, Americanii au făcut o descoperire uriaşă în Afganistan: minereuri în valoare de circa un trilion de dolari, in Adevărul, June 14, 2010

lithium is the raw material for batteries and some parts of laptops, mobile phones and other devices, from the pocket to cosmic shuttles!

The value of the newly discovered mineral deposits puts in a new light the Afghanistan economy, based especially on opium production and drug trafficking as well as on the aid from the United States and other industrialized countries. Afghanistan's gross domestic product is only 12 billion dollars. American and Afghan officials have agreed to discuss about these deposits extremely valuable in a difficult time of war.

American officials acknowledge, however, that the mineral discoveries will have, almost certainly, a double-edged impact. Instead of bringing peace, mineral wealth may require the Taliban to intensify their struggle to regain control of the country. However, corruption, which is already quite high in Karzai government could be amplified by the new wealth, particularly if a handful of oligarchs who have personal ties with the president take control of resources.

Last year, the Afghan minister of mines was accused by American officials of accepting 30 million dollars bribe to award China the rights to develop copper mines. The minister was later replaced.

Experts believe that without "its mining culture", it will take decades until Afghanistan will be able to fully exploit the minerals. Mineral deposits are scattered throughout the country, including in the south and east regions, along the border with Pakistan, where there were recorded the most intense battles in the war led by Americans against Taliban insurgents.

The Pentagon has already begun to help Afghans set up a system to deal with mineral development. International accounting firms that have expertise in mining operation contracts have committed to consult with the Afghan Ministry of Mines, and technical data are ready to be delivered to multinational mining companies and other potential foreign investors. Pentagon helps Afghan officials in their efforts to seek bids on mining operation since the autumn of 2011.

China could provide in this new context exactly what is missing in Afghanistan: machinery for extraction. Afghanistan is totally deprived of mining infrastructure and it will take maybe decades until it can get profit from these deposits barely discovered. "This country has no mining culture," said Jack McEdlin, American geologist involved in geological prospecting. It has some small artisanal mines, but now it takes a lot of mines, much larger, which require a little more than a «colander»".

It is not actually one giant deposit: the whole country seems to be crammed with mineral deposits; the discovery seems to have been made possible thanks to some old maps found in the library of the Afghan Geological Institute in Kabul, maps presenting most mineral deposits of the country. These maps and satellite mapping have been studied since 2004, and American geologists have confirmed the data collected by Soviet geologists; they proved the existence of some huge mineral deposits. "There were maps, but the mining development could not start because of the 30-35 years of war," said Ahmad Hujabre, Afghan engineer in the Ministry of Mines.

Based on these maps, American geologists have made aerial prospections with a satellite Orion P-3 of the Navy, over about 70 percent of Afghan territory, obtaining three-dimensional results of underground mineral deposits, results which were astounding: deposits of copper, iron and REE are so important that it could make from Afghanistan one of the major world producer; the labelled deposits contain niobium, rare metal, particularly important for the manufacture of rockets, nuclear energy, condensers and for producing the niobium of lithium, a crystal capable of changing the refractive index, and therefore used in the manufacture of high-capacity optical fibres. There are also very large gold deposits in Pashtun, as well as huge deposits of lithium in the province Ghanzi. The news of the discovery of these deposits remained silent for many years or was deliberately ignored.[16]

Australia

Lynas Company, which has a deposit in the region Mount Weld in Western Australia will be able to develop this mining project thanks to a long-term supply contract with Rhodia. For reasons of environmental conservation, this company stopped the REE extraction, starting with the monazite, associated to the sands of beach containing titan, in the operation located near La Rochelle.

Bolivia

Since 2009, Bolivia announced that can supply the world with lithium for at least the next 5,000 years[17]. And it wants to exploit this precious mineral alone, without appeal to foreign industries.

[16] on the website http://www.ditadifulmine.com/2010/06/scoperti-enormi-giacimenti -di-minerali.html, visited in June 24, 2010

[17] after Clara Delpas, *Bolivie: le lithium se fait attendre,* on the website www. novethic.com, visited in December 7, 2010

Japanese companies - Mitsubishi and Sumitomo, Korean companies - Kores, Hyundai and LG, Finnish companies- European Batteries and French companies - Bolloré and Eramet want to exploit more than a decade Bolivian lithium. In late October 2010, they were announced by Bolivia that only at the horizon of 2014-2015 can expect to possible partnerships in this regard. Until then, Bolivia wants to endorse alone the exploiting of this precious mineral.

Lithium is the raw material for manufacturing latest generation battery for cars, especially electric cars, portable phones, I-pods, personal computers. The fact that Bolivia remains mistress of its resources is a challenge: the country must get out of poor exploitation sign of raw materials, fact which dates from the occupation period by Spanish. For, despite the considerable mining riches they possess - silver, gold, tin - Bolivia remains one of the poorest countries in the world.

Although lithium deposits are expected to bring wealth in Bolivia, nothing is less certain that they will become operational. Since 2008, Bolivia announced it wants to begin operation of this light and soft metal, which is abundant on the surface of its salty lakes in Andes. But 10 years after its neighbour state, Chile, began to do so; Chile is now the first world producer of lithium.

Bolivia does not have even a pilot plant whose operation was announced in late 2010, but in May 2011 it was still under construction! If Evo Morales predicted "a revolution of the global energy die" due to Bolivian lithium exploitation, he announced then that industrial phase of the project is provided barely in 2014-2015, if there will be no delay again...

First, Bolivia must catch up Chile, which supplies at export about 40,000 tons of lithium carbonate annually. Almost 10 times more than the current Bolivian pilot plant capacity. Bolivian State should invest 900 million dollars to develop a competitive industry in the field. Or, funding pilot plant has just collected the 7 million dollars needed for its delayed entry into service and there has to be build other 8 plants for the extraction of lithium carbonate and other mineral components likely to interest chemical or phytosanitary industry (fertilizers of soil), elements as boric acid, chloride and potassium sulphate, etc.

Bolivian resources of lithium are considerable – they were estimated to an amount of 24 million tons by American geologists and 100 million tons by Bolivian experts, i.e. about 33 times higher than the Chilean reserves. Their exploitation should not fret local populations who have not yet obtained any benefit from them[18]. Mining activity of the pilot plant has not generated the expected occupation of human resources, about 100 miners of this plant, being delocalized employees by Mining Corporation of Bolivia (for short COMIBOL); operation with one pilot station has not improved at all the locale infrastructures. Electricity, made at great expense in the pilot plant zone is increasingly desired in surrounding villages. Regarding environmental impact, residents and NGOs stir because of the threat to the water resources of the region, especially in the zone Salar de Uyuni.

In this area already very deserted - Salar is the largest salt desert on the planet - it lives mainly from the quinoa culture and tourism. Pilot plant of producing lithium lies not far from the Rio Grande River, a proximity which increases fear of water quality pollution. For now the only solution adopted by COMIBOL to treat mining waste resulting from the extraction of lithium is to store it in a special place on a dried up arm of the river, hoping that the rainy season will not affect their reabsorption into the soil.

Tim McKenna, vice president of Chemetall, the American company that shares with the Chilean company SQM, 70 per cent of exploitation lithium from the salt desert Atacama said: "In Chile, we have had 15 years of attempts to achieve industrial production levels. And with no geographical and logistical obstacles that Bolivia knows". Because the country has no suitable infrastructure for the access to the sea. Seen from this perspective, the term 2014 seems unrealistic. Provided Bolivia decide to take an ally consisting of a foreign industrial firm. Conglomerates specialized in the industrialization of lithium are already tuned[19].

Canada

In June 3, 2010, the Canadian company Dios announced that it discovered several deposits containing REE in the complex of carbonates in Shipshaw, near Saguenay, Quebec, located at 7 km from niobium mine and infrastructures for ferrous-niobium operation owned by the company Iamgold[20]. A series of 90 analysed rock

[18] Rebecca Hollender and Jim Shultz, *Bolivia and its Lithium. Can the "Gold of the 21st Century" Help Lift a Nation out of Poverty? À Democracy Center Special Report*, on the website http://democracyctr.org/pdf/DClithiumfull-reportenglish.pdf, visited in May 9, 2010

[19] on the website http://www.litiobolivia.org/en.html, visited in May 10, 2011

[20] press release prepared by Marie-José Girard, M.Sc. Géo., a qualified person under the Norm 43-101, Exploration Dios Inc., Marie-José Girard, president

samples highlighted niobium reaching 0.053% Nb205 (niobium oxide), 12% P205 (phosphate, apatite), very high content, and 0.487% TREEO (oxides composed of rare metals, excluding yttrium and zirconium). TREEO compound varies in deposit depending on the depth of operation between 0.172 and 0.700%.

The first well was drilled almost vertically in the weakest part of the magnetic anomaly containing only 6 feet of so-called "dead land" situated over 11 meters of sediments from the Ordovician period, situated above the metalliferous complex. What is interesting to note, according to the analysed samples is that the first meters of deposit have the following content of niobium and REE: 0.022% Nb_2O_5, 0.228% TREEO and 0.253% ZrO_2 (zirconium oxide).

Geological drillings made by Dios have confirmed the discovery of a parallel deposit, where there were analysed 15-20 samples for evaluation of the content in niobium and tantalum of the carbonate complex Shipshaw.

Gabon

At the end of August 2010, the Gabonese state announced its involvement in the activities of the foreign company Eramet and its Gabonese subsidiary Comilog. Patrick Buffet, CEO of the mining group and the president Ali Bongo Ondimba, evoked various joint projects in the field of REE. Gabonese state allowed subsidiary Comilog the research of the deposit Mabounié containing niobium, REE, tantalum and uranium to assess its potential for exploitation.

Republic of Moldova

40 years ago, in the Soviet Socialist Republic of Moldova, REE were used extensively in more than 20 industrial branches[21]. Among the most important fields of application of REE there were since then: metallurgy and equipment industry, glass and chemical industry, electronics, radio-technics and contemporary radio-electronics,

and CEO, e-mail:. mjgirard@diosexplo.com, on the website www.diosexplo.com, visited in October 1, 2010, at 12:29

[21] according to Iuliu Pop, *Magnetismul pământurilor rare*, Bucharest, Academy Publishing House, 1968 and Милованов, Г.Н., Черносвитов, Ю.Л., *Редкоземельные элементы*, Госгеолтехиздат, Москва, 1959, quoted by Popuiac A., *Aspecte generale din geochimia pământurilor rare din nord-estul Republicii Moldova,* in the Bulletin of the Institute of Geology and Seismology of the Academy of Sciences of Moldova, no. 1, 2009, p. 29-40

medicine and pharmaceutical technique, optical and lighting technique, aviation and cosmic, shipping and military technique, jewellery production and agriculture.

After A. Popuiac[22], REE production is widespread in India, Brazil, Austria, England, France, Germany, Russia, China. In the U.S.A., the development and improvement of enterprises producing essential REE is stimulated by the government and NASA. In the central region of the Dniester river basin, over several decades it has been conducted a complex geological study aimed at determining the metallogenic features of geological formations in this area. Based on geological and geochemical data obtained by the Institute of Geology and Seismology of the Academy of Sciences of Moldova and the State Geological Agency in Moldova (for short AGeoM), the territory from the central basin of the river Dniester is considered promising in terms of detection of mineralization of radioactive elements, rare metals, iron, zinc, lead, barite, including REE. Concentrations of REE (TR), represented by lanthanum (La), cerium (Ce), ytterbium (Yb), yttrium (Y) and scandium (Sc) were found in terrigenous formations in north-eastern Republic of Moldova.

U.S.A.

United States of America, which were once world leader in the production of REE, exploited until 2002 a deposit in Mountain Pass, California. Mountain Pass mine does not contain significant amounts of dysprosium, vital element for the so-called permanent magnets, used in the manufacture of many essential components of the American defence system.

In April 2010, in the American Congress it was urgently discussed a report on the vital role of REE for the American economy. On the website of U.S.A. Congress, it could be read then that "REE are essential to developing technologies that produce renewable energies; these technologies allow U.S.A. to reduce their dependence on oil and reduce emissions of greenhouse gas. Chinese will is to limit its exports in this direction and thus to make an issue of U.S.A. competitiveness, and we must, on the one hand to ensure supplies and, on the other hand, allow the development of mines to extract REE from American subsoil. U.S.A. cannot depend 100 percent on imports from China.

[22] A. Popuiac, *Aspecte generale din geochimia pământurilor rare din nord-estul Republicii Moldova,* in the Bulletin of the Institute of Geology and Seismology of the Academy of Sciences of Moldova, no. 1, 2009, p. 29-40

"The American administration in Washington wanted a law to encourage exports of REE in U.S.A., somewhat delayed after the reaction of China to establish the embargo on its REE.

Given the lack of American production of REE, U.S.A. was forced to buy these strategic raw materials from China, the source of about 90 percent of these minerals, thereby setting market prices. Therefore, the Americans decided that a priority for American industry to seek such rare mineral deposits, so that U.S.A. be released by the "Chinese dependency".

Report of April 2010, presented in the U.S.A. Congress, was conducted by U.S. General Accountability Office estimated that they will have to pass about 15 years before U.S.A. be able to rebuild its own industry of rare elements - and this if it can be resolved a number of legal, technical and financial issues. In its turn, Pentagon issued a report about the military vulnerability of U.S.A. in this case. U.S.A. Energy Department is working on its own plan, and House Armed Services Committee has scheduled a hearing on the subject.

In April 2011, Molycorp Minerals, an American company established in Colorado, has made known a plan of 500 million dollars U.SA. for the renovation of the Mountain Pass mine in the Mojave Desert (California. U.S.A.) which, prior to its closure in 2002 due to Chinese competition in domain and environmental concerns (use of solvents for the extraction of REE). Molycorp Minerals was the leading producer of REE.

U.S.A. decided also to create a stockpile of REE, as did Japan and South Korea. After a complete technical rehabilitation by returning to compliance with the current norms of pollution, Mountain Pass mine was reopened again in 2012.

3.3. Potential of reserve of deposits operation

In 2011, there were over 312 exploration projects of REE deposits reviewed on the planet, involving over 202 companies of very diverse class from about 34 countries. REE mines from Mountain Pass, California (USA) have been the subject of significant investments to limit the hegemony of Chinese production of rare metals; it is also studied reopening some south-Africaine mines[23]. Some Canadian

[23] ***, *Matieres premieres: l'OMC condamne la Chine*, in Les Echos, January 9, 2010

deposits (such as the one from Hoida Lake), Vietnamese, Australian and Russian deposits are also under evaluation.

In July 2011, a team of Japanese scientists from the University of Tokyo, led by researcher Yasuhiro Cato, announced that he discovered a new REE reserve in international waters of Pacific[24], which would raise the level of known reserves currently at about 110 billion tons; same source indicates that reserves are distributed in 78 sites located at depths from 3,000 to 6,000 meters in the international waters around Hawaii and Tahiti islands. In the richest areas in REE from Pacific, Japanese researchers have given assurances that the operation of deposits located on an area of 5 km^2 can cover global demand of such resources for a year. Even if the discovery is interesting, given the increasing demand for these raw materials, their extraction raises significant environmental problems.[25]

Japanese experts discovery is very important.[26] After Craig Smith, oceanographer at the University of Hawaii, the extraction of REE from oceans and marine environments requires the same as on terrestrial ground acid baths according to current technologies, which could have a particularly detrimental impact on those marine sites; they shelter fragile ecosystems, where many endemic species inhabit.

Yasuhiro Kato, one of the authors of rare metal deposits discovery off the Japanese territorial waters ensures us that the operation process of them will not pose any danger because the sites more acidic of water will not be poured in the Pacific Ocean, but will be filtered for the separation of harmful compounds. To appease the spirits, the Japanese expert said that operation in trade regime of REE deposits off the Japanese coasts will not start sooner than 20 years, enough time to improve current technologies of separation. However, discovering these huge reserves off the Pacific Ocean may overshadow the Chinese monopoly.

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[24] on the website http://www.futura-sciences.com/fr/news/t/developpement-durable-1/d/des-terres-rares-au-fond-du-pacifique_31280/#xtor=RSS-8, art. *Des terres rares au fond du Pacifique*, visited in July 19, 2012, at 5:11 a.m.

[25] ***, *Mongolie: les terres rares empoisonnent l'environnement*, on the website http://www.novethic.fr/novethic/planete/environnement/pollution/mongolie_terres_rares_empoisonnent_environnement/132199.jsp, visited in July 19, 2012, at 5:19 a.m. and ***, *Grandes manoeuvres autour des metaux rares,* in Le Monde, February 3, 2010

[26] sources: Bruno Scala, *Des terres rares au fond du Pacifique,* on the website www.Futura-Siences.com, visited in July 19, 2012, at 20:48 and Yuriko Nakao, *Des terres de moins en moins rares,* Reuters, July 6, 2011

Under cover of environmental concerns, the Chinese authorities notified American authorities at the end of 2010, China's desire to gradually reduce its exports of REE. When after 1985, Chinese politician Deng Xiaoping realized the strategic importance of control of these metals, China did not evaluate, nor tabulate only a quarter of its reserves of REE, which propelled it on the first place in the world. Then exporting at unbeatable prices, China has prevented any foreign competition, but without solving the waste problem resulting in the environment became thus very fragile. "Logically, Chinese monopoly should erode over the next 5 or 10 years, but it requires a deliberate effort to recycle REE, as well as to establish a strategic stockpile", estimated in March 9, 2011, François Heisbourg, special adviser to the Foundation for strategic Studies, who expresses in this respect in front of a committee of the European Parliament Office to assess scientific and technological choices (OPECST).[27]

3.4. Recycling products containing rare metals

Essential today in green technologies, based on rare metals (see Chapter 4) is gallium, used to make LEDs, as well as indium, used for LCD type screens (liquid crystal display). Indium is also used for the construction of new generation photovoltaic panels (CIGS), which already operates in French complex Saint Gobain Solar[28]; the latter case is particularly interesting because indium is a rare and expensive metal (costing about 600 dollars per kilogram), is sold in combination with silica, which is found in large quantity, which allows to the said mixture a better performance, but finally it returns more expensive; world annual production of indium is about 1,200 tons. In 2020, it aims to stabilize the use of indium up to 10-15 tons per year, following the idea of including this rare material in recycling programs of solar panels used currently.

In order to secure the supply of rare metals, industrialized and emerging countries, which depend on the use of these metals must act on three tracks:

1. reduce their use;
2. diversification of sources, opening new mines or reopening mines abandoned in front of the terrible competitiveness of REE in China;

[27] Béatrice Héraud, *Terres rares: l'enjeu du recyclage*, on the website www. novethic.com, visited in April 4, 2011

[28] idem

3. recycling REE.

The most important strategy to recycle REE seems to have belonged to a French company, Rhodia. On 4 April 2011, Rhodia whose main activity was the recycling of rare metals, was acquired by Solvay et Silmet, whose capital was then purchased by Molymet company and thus resulted Molycorp Silmet, first world producer of REE, which thanks to the activities carried out, is no longer dependent on Chinese exports.

Currently, Molycorp Silmet is world leader of REE use; although it aims reducing the REE use exploited from deposits, Molycorp Silmet has signed a partnership for 10 years with Linas Company to exploit REE resources of Mount Weld mine, located in west of Australia.

Cases requiring recycling of rare metals

Thanks to this partnership, Mount Weld "urban mine" began in 2009 to apply in parallel with extraction, a new method for recovering and separating REE contained in used consumption bulbs. In these products - few people know - there are indeed 5-6 REE, including terbium, yttrium and europium, among the most difficult to find and separate, which makes them very expensive on the market: terbium is sold today in Europe at the price of 800 dollars / kg, compared to only 500 / kg in early 2010. Also, the use of terbium will increase in composition of several products, some of them considered strategic.[29]

After a study carried out by ADEME Company, which is based on forecasts of supply over demand in 2014, supply the world market with terbium and yttrium appears to be critical which makes it again be discussed recycling process of these rare metals. Collection pathway of used lamps is now well established in EU countries. In 2010, there were about 19,000 collection points in EU countries, and one recycling company - such as French eco-organism Recylum - managed to collect 3,650 tons fluocompacte[30] lamps. From them it "can be extracted 15 tons of yttrium, 1 tone of terbium and 1 tone of europium, exactly as they are now European needs", as the director Recyclum, Hervé Grimaud said; resulted luminophores powders, rich in these REE, thus can be made, almost free, at Rhodia disposition to be recycled and reintroduced to productive flows that require them.

This request for recycling large-scale, European – at the system participates with more or less success, all 27 EU countries – is not the

[29] idem
[30] ibidem

first attempt of this kind. In early 2000, Rhodia had launched a project to recover REE contained in the catalytic pots, but it was finally abandoned for economic reasons.

In their essence, REE recycling processes are complex and costly. Thus, in order to set up a method for recycling REE, it takes about 3 years of research and development (only at the French company Rhodia, 50 researchers work in such a method) and the investment of 10 million euro, underlines Frédéric Carencotte, industrial director at the company Rhodia Rare Earth. "Economic profitability should not be the first criterion leading to admission of such a project," he admits, but "contribution of recovered rare metals have to diversify our resources and sustainable development. The fact of getting terbium 100 percent recycled many customers are interested. We have to wait a little longer to make a true supply with recycled REE".

Also in France there is a REE recycling company in the town Saint-Fons, which was to produce in the first half of 2012, several hundred tons of recycled REE. And in 2014, a new industrial plant to recycle REE earths will be operational in the town La Rochelle, still in France.

At the end of the first quarter of 2012, Rhodia was the only REE recycling company in Europe, "able to refine and separate REE", said Frédéric Carencotte member of Rhodia personnel. Worldwide there is a battle unseen, where impressive forces are invested in people and money (given the prevalence of the system for strategic and military technologies, the sums and the amount of money invested are however not known) to move slowly, on grounds of economic, social and ecological efficiency, to recycling all REE, with industrial applications today or in the future.

In Japan, for example, more than 5,000 researchers work on this vital issue for this country devoted to the application of new technologies. In early 2012, the Institute of Industrial Sciences of the University of Tokyo announced that applies in a pilot plant a method that allows recycling neodymium in a percentage of up to 80 percent of consumed products that contain it.

This REE is still very desirable, especially in green technologies: a Prius car engine, for example, requires 1kg of neodymium to utilize it for its magnetic properties. To satisfy the needs for this rare metal of the current fleet of Japan, it would be necessary about 700,000 tons of neodymium, which obviously cannot be obtained only from current mining deposits, deposits in which Japan does not have at all.

In the above calculations, made only for a make of car and only for a country, it is added equally vast offshore wind turbine market, which consumes up to 600 kilograms of rare metal on a turbine to improve functioning and decrease maintenance costs ... Calculations, obviously partial and incomplete, show that about 8 million tons of that metal, already used in current turbines, expects to be recyclable when they will be decommissioned. Meanwhile, it will be put in place the method of recycling that rare metal, as well as new technologies to increase the reliability of wind turbines.

Some experts doubt that will ever be overcome current technological limitations related to the recycling of REE, and then of rare metals. Doubt is a human quality, but which contributed to the current scientific progress. Jean-Claude Samama, former director of Higher National School of Geology in Nancy and emeritus professor of applied geology and Benoit de Guillebon, director of Apes (Technical Centre for Environment and Mastering Risks), authors of the book along with Philippe Bihouix "Quel futur pour les Métaux?" ("What future for metals?") show in their book recycling metals limits. After them "recycling at a high cost, makes only delay waiting a few years. When the amount of energy required to extract rare metals will double, we must change imperative the view to look at things and current production way will focus on eco-design, especially in terms of rare metals."[31]

[31] ibidem

Chapter 4
RARE EARTH ELEMENTS. CIRCULATION AND CONSUMPTION

4.1. Areas of application

Specialists have been studying rare earth elements for about three decades because of their unusual properties which highly recommend their use in the economic and scientific environment. REE are used to produce wind generators, electronic parts and assemblies, metal separators, motors, clutches and other auto parts, lifting and extraction devices.

Very few people know that REE are used to produce components for lasers, mobile phones, computers, iPods, sonars, LCDs, washing machines, hybrid cars, digital cameras, headphones, batteries for electric vehicles, missile guidance systems, smart bombs and space crafts. Despite the name “rare earth elements” they are not that rare, but are usually found in small volumes spread on large areas and require complicated post-processing, which makes most existing deposits expensive to use[1]. The economy of the production and use of rare earth elements and the sophisticated technology based on them is called the economy of rare earth elements and is absolutely vital to modern civilization.

Inductive coupled plasma spectrometry (ICP-MS) offers the possibility of measuring rare earths with excellent accuracy that can`t be achieved by any other method. In addition, ICP-MS is capable of measuring isotopic reports. REE and isotopic reports represent a real fingerprint and provide information about pollutant sources in the environment.

In the long run, these chemical elements are very rare and there are huge financial and environmental costs involved in the extraction and

[1] ***, *Avatar pe Terra: pământurile rare sunt seva civilizației*, on www.descopera.ro, 16th of March 2010

production process. In the next 5-10 years, 97 percent of the global production of REE will belong to China. However, China, which is already reluctant to exporting, wants electronic manufacturers to come and produce in China and only then to have access to the Chinese REMs, indispensables to the electronic industry today[2].

Annual global consumption of rare earth elements, expressed in oxides, was estimated at 25.000 tons per year at the beginning of the last decade, the first of the 21st century. Early this decade the current global consumption was estimated at 40.000 tons, although the real demand is three times bigger and the potential demand for 2013 is 5 times higher. The demand for REE in 2012 was about 120.000 tones.

Rare earth metals have unique properties that make them useful in many applications and their use increased at the end of the 20th century. Neodymium, dysprosium and samarium are used to manufacture compact magnets for the synchronous electric motors. Yttrium trioxide (Y2O3) is utilized in metal alloys to enhance their corrosion and high temperature resistance. Rare earth oxides are used as pigments, particularly red, for example, to replace chromium oxide and also for their fluorescent properties, especially in neon discharge lamps, compact fluorescent lamps, the nets for the gas lamps for camping and recently in the technology of various lasers.

The combination of rare earth elements are used as mixtures of rare metals called "mischmetal", generally rich in ceric soils. Due to its properties, a large part of cerium production is incorporated into alloys used to produce lighter stones. It is also used as a catalyst to absorb hydrogen (as a tank). The normal bulb glass has in its composition, as pigment, terbium which is a rare earth.

The world today consumes only a small amount of rare earth metals - about 130.000 tons per year, a bit less over 10 percent of the products made by copper oxides. Economic analysts expect that global trade with rare earth metals will reach $3 billion by 2014 from about $2 billion in 2009.

Rare earth elements have low worth in their natural state, most of their value being added after the refining process.[3]

The main uses of REE are:

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[2] Adrian Buzatu, Tehnologiile moderne au nevoie de pământuri rare, iar ele sunt ... rare, URL: www.stiintaazi.ro, 21st of March 2010

[3] After Charles Homans, Are rare earth elements actually rare?, in Foreign Policy, 15th of June 2010, URL: www.Foreign Policy, visited on the 19th of September 2010

Dysprosium[4] (has a silky, silvery appearance. 90 percent of this rare earth is extracted in China through a laborious and expensive process):

Magnets for hybrid engines (gas/electricity). The use of dysprosium makes these engines 90 percent lighter.

Lasers and computer hard drives

Terbium

Increases the efficiency of neon tubes by 80%;

Neodymium

Permanent magnets for the electric motors

Lanthanum

Hydrogen storage

Praseodymium

Lasers and ceramics

Gadolinium

Computer memory

Erbium

Manufacturing of vanadium-steel alloy

Ytterbium

Infrared lasers

REE represent an important strategic resource. When we say that, we don`t just mean the “traditional” applications based on rare earths for more than 150 years such as catalysis for oil refining into gasoline and medical radiography etc. But in addition, modern procedures based on rare earth elements including:

– Catalysis of car fumes based on cerium which removes the particles produced during the diesel combustion.
– Polarization of flat or luminescent displays, using terbium to manufacture luminescent tubes or electroluminescent diodes (LEDs) or plasma displays, LCDs and flat panel displays.

More technologies based on rare earth elements are being developed: yttrium based superconductors and magnetic refrigeration based on gadolinium.

[4] In Greek means “hard to get”.

By increasing the production of electric motors based on permanent magnets made of terbium-dysprosium or neodymium, large industrial applications based on REMs have an environmental beneficial effect by:

– building hybrid electric vehicles
– electric generators for offshore wind turbines. The sea environment is highly corrosive. The structure of a wind turbine of 3 megawatts can contain 600 kg of neodymium which gives better functioning and maintenance indicators under these rough conditions. Wind turbines use two types of neodymium for their powerful permanent magnets.

Other components used in most modern cars require small amounts of rare earth metal as europium, yttrium, cerium, zirconium, terbium, praseodymium and dysprosium.

On the other hand, while the global need for rare earth elements is increasing, about 10 percent each year, China reduced to zero the export quotas in 2010. Such a development has alarmed the industrial giants of the world: The U.S. imports from China REE worth over $ 1 billion annually. The high tech technologies of Japan and the European Union are also dependent on the rare earth elements from China. New systems and factories able to handle the extraction and separation of REMs may become active in less than 4 to10 years.

Although the prices of these minerals have increased in recent years, REMs production is still less profitable than copper or iron. Cerium is a precious ingredient in enamels and glass lenses; europium is used in the production of displays for TVs and other screens. The military industry is based on the rare earth elements which are important for lasers, missiles, radar systems and other military technologies. It is anticipated that China's demand for REE will exceed its capabilities of supply by 2015.

The Americans are taking their steps in this field. The American company Molycorp Minerals bought a new mine at the Mountain Pass and Avalon Rare Metals started to organize the conditions to process large REE deposit in the Northwest Territories of Canada.

In 2010 there were only two future rare earth elements mining projects outside China: Mountain Pass in California and Mount Wells in Australia. China argues that it needs the REE it produces for its own developing industries. In 2010, China consumed about 60 percent of its own production. China's efforts to bring at surface and separate rare earth metals are notable. To better exploit its underground wealth, China also wants to produce economic goods which incorporate these REE and it should develop its economy by creating 300 million jobs by November 2020.

The Western governments are worried about the Chinese monopoly exerted on REE, due to the fact that REMs are being used to build missile systems. Dysprosium, for example, allows missiles to operate in extreme conditions. The U.S. Army doesn't want to buy it on the open market. The U.S. needs a guaranteed supply and this has become a problem. If China were the only place on earth to have rare earth metals, this could lead to a planetary war. Fortunately, there are other reserves of REE and the welfare states made sure that they have reserves in this regard.

In this context, China is building slowly but surely her planetary domination, knowing the problem it is creating for the western world.

In recent years, the Chinese government got all mines and refineries dealing with REE under the umbrella of Boatau Steel, a state owned company in order to easier control the prices.

The minerals found in the rare earth elements are the key to the development and manufacturing of essential components in the field of clean energy technology, automotive and electronic industries. They are essential for almost all environmentally friendly technologies such as wind turbines, solar panels and hybrid engines.

The Chinese Summit on Rare Earth Elements

In order to promote the industry, the science and the technology of REE, China has been organizing since 2005 a Summit on rare earth elements through The Chinese Society for Rare Earths. The 2010 meeting was held between 2-6 August, in Beijing, under the name of The International Conference on Development and Application of Rare Earth Metals. The theme of the Conference was "China`s policy on the industry of rare earths and the world economy of rare earth elements". The event was aimed at building a platform that ensures a better understanding of the industrial policies on REE in China and worldwide for the companies in the field. It was an occasion to exchange ideas on the problems of the global REE resources, production, environment and marketing, in order to help promote this industry at a global scale.

The Forum focused on the impact that China's policy on REE industry has on dependent industries, the relationship between new renewable energy industry and REE, the current state and trends of REMs new materials and REE industry influence on the environment etc. Conference website: http://www.cs- re.org.cn /asc/.

The invitees at this summit were leaders in governance, entrepreneurs in the field of production of REE, users and traders of REE, experts and scientists from all over the world. For detailed information see the conference web page: http://www.csre.org.cn/cres/.

The Chinese Society for Rare Earth Elements (CSRE)

Founded in 1980, CSRE is an organization with a scientific and technological research purpose regarding REE. It has as members several thousands of registered experts, being the largest academic community in the field of rare earth elements in the world.

CSRE gives the researchers the chance to exchange ideas about their work, to propose scientific and technological plans in the field of REE and plans for research and development in the industry of REE. Contact: Dr. Chen Zhanheng, Deputy Director, Chinese Society of Rare Earth Elements, tel. and fax: 0086-10-62188304, Email: chenzh@cs-re.org.cn, web: http://www.cs-re. org.cn

4.2. Rare earth elements stimulate the growth of green technologies

Rare earths are widely used in the construction of car engines, in electronics, military and nuclear industries. They represent the raw materials for high-technologies, especially IT, lasers, mp3 etc. Rare earth elements are used to produce batteries - lanthanum based – vital for electric cars, which are slowly replacing petroleum-based ones thus fostering green growth. Neodymium is used to produce highly efficient magnets for electric motors, hydroelectric or wind turbines and hybrid cars.

Professor Animesh Jha, with the Faculty of Engineering in Leeds (UK) has developed a simple and less expensive process to the recovery of titanium dioxide (TiO_2) from industrial waste.[5] "There is a serious risk that the development of technologies that have a major impact on the environment can be slowed down by the shortages of rare earth elements which have lately become essential raw materials for many

[5] Grégoire Macqueron, *Des terres rares en abondance pour les technologies vertes?,* URL: www.Futura-Science.com, visited on the 19th of July 2012, at 8,15 am.

processes," says Animesh Jha, who argues that "his new method, "greener" than current technologies could reduce this very likely risk".

The titanium dioxide recovery rate from industrial waste varies between 60 and 80 percent and the procedure developed by professor Jha might be able to increase this rate in the future. The recovery of neodymium oxide, cerium and lanthanum from the production waste started already and registers a double benefit for the environment: the process allows the recycling of industrial waste and the separation of titanium and rare earth elements.

On an industrial scale, this new method could fight the Chinese Monopoly production of REE and ensure the development of green technologies and also information and communication technologies (ICTs).

4.3. Industrial applications

The current industrial applications add value to REE and their particularities.

In metallurgy, REMs are used to enhance and strengthen the properties of cast iron or steel. Used very often as structural additives, they allow the morphology control of the inclusion of sulfurs in acids, to improving the ductility, thermal and mechanical resistance.

In the field of catalysis, the chemical properties of the rare earth elements are important in improving the stability, the activity or the selectivity of the catalytic systems. Thus, the multi-functional catalysts based on rare earth elements allow the reduction of the compounds of carbon monoxides and nitrogen in the exhaust gases.

In the composition of the catalyst for the exhaust gases there is precious metal deposited on an aluminum support which is treated with cerium oxide. Thanks to its oxidation reducing properties, cerium oxide plays the role of regulating the proportion of oxygen in the gas mixture, thus achieving the best possible catalytic and global activity.

Industrial applications of REE in the fields of pottery and glass are multiple: neodymium gives the purple color, praseodymium the green color, erbium the pink color of crystal or eye glasses. Cerium combined with titanium gives a vivid yellow color, often used in kitchen products, but the main use is in the field of discoloration - this combination oxidizes some colored impurities (bivalent iron, for example) and, because of its strong absorption of electrons and ultraviolet rays, it helps to avoid the blackening of glass under the effect of these radiations (windows, bottles, wind screens etc.) Lanthanum is used to obtain borate glass with a high refractive index and low dispersion indispensable in precision optics (photographic and microscope lenses, for example).

Quasi monochromatic luminescence emissions are successfully used to achieve an exceptional performance in television, lighting or radio luminescence.

The property of being luminophores of REE enables the production of trichromatic fluorescent tubes. The ultraviolet radiation emitted by the mercury drops, “stimulated” between two electrodes is converted into visible light using three luminophores whose activators emit one of the fundamental colors: bivalent europium for blue and trivalent europium for red and terbium for green. The yields and lifetime of the neon tubes treated with these rare earths are often superior to those of the traditional incandescent lamps.

In radio luminescence, an intense absorption of X-rays, an excellent yield of conversion in visible light and a wave length well suited to maximal sensitivity of the photographic emulsions used make the luminophores of the REE the preferred materials when it comes to producing the displays used to transform a radiological medical image into an optical image.

Exceptional magnetic properties of the alloys made from mixing an element of transition and a REE are highlighted in the composition of permanent magnets - these are the most effective combinations: $SmCo_5$, Sm_2Co_{17}, $Nd_2Fe_{14}B$. The most spectacular consistency of their use was the miniaturization of the magnets that allowed a high fidelity, for example the magnetic alloy based on Sm_2Co_{17} decreased the volume of the microphones or headphones.

On the other hand, the decrease in the costs and the excellent magnetic properties of neodymium magnets enabled the replacement of the electromagnets mainly in the automotive industry. Rare earth elements are sometimes used in very small percentages, but the magnets are extremely important in the production of motors for hybrid cars, and high-speed trains. REE are also important in the production of strategic positioning devices (GPS), liquid crystal displays (LCD) or tactile devices and mobile phones, especially the batteries.

It is almost certain that the prices for rare earths will greatly increase in the following years. This situation creates a huge investment opportunity for the countries that possess such resources and their companies, for transnational companies and businessmen willing to invest in this field.

There is another great opportunity for large investments in the field of recycling the rare earth elements. When the cost of extraction exceeds the cost of recycling, it will be more lucrative to recycle the REE from scrapped computers, displays, sound systems, batteries etc. Therefore, recycling is already a matter on the table of the decision makers.

A smart entrepreneur could make a fortune by recycling and selling the REE which otherwise would be extracted at higher prices from the REE deposits. A hundred years ago, nobody could have imagined that 85 percent of all lead used today is recovered from batteries and similar devices having lead in their composition. But in the last fifty years, lead recycling has become an important activity all over the globe due to its technological importance over the last decades.

4.4. The policy of the U.S. Department of Energy Policy in the field or REE

Ever since October 2010, the US Congress has been supporting companies through a loan guarantee program, to relocate their mining activities and production of REE in the US. The new mines could reach full production capacity in 3 to 5 years from their opening or reopening[6]. Also, the existing uranium mines could provide rare earth metals by reprocessing all the material excavated so far, which often contains these metals.

The Deputy Secretary of the U.S. Department of Energy, David Sandalow announced in March 2011 that his institution has developed a strategic plan regarding the use of rare earth elements and other materials used in the field of clean technologies, focusing on the research for substitutes and promoting the recycling, reuse and a more efficient use of REE, while “encouraging our trading partners to speed-up the process of creating alternative and environmentally friendly sources of exploitation of rare earth elements.” The correspondence between the specialists of the U.S. Department of Energy and their Chinese counterparts in the spring of 2011, led to the conclusion that the necessary agreements have already been established between the two most powerful countries in the field of rare earth elements.

[6] Hot News, October, 20, 2010.

The experts believe that the U.S. encourages and finances the extraction, refining and manufacturing of rare earth elements in China.

Under the loan guarantee program which helps rebuilding the domestic supply chain of REE, the U.S. Department of Energy also encourages any well documented and substantiated request made in this respect. This means speeding up the applications related to "production of rare earths elements of high purity, production of metals extracted from rare earth elements, production of alloys based on REE, manufacturing permanent magnets, advanced batteries and other components of rare earth elements associated with clean energy technologies." Giving loan guarantees to companies in these areas allows funding of projects with a better interest rate and a lower cost than usual. The loan guarantee granted by the U.S. government reduces the financial risk for the creditors and represents a vote of confidence given by the U.S., which can help a company to attract capital investors.

The Federal Government promotes as a priority the documents regarding the REE in the supply chain of the Department of Defense.[7]

The law in this regard was signed by President Obama, and it stated that "no later than April 1, 2010, a report regarding REE and their role in the supply chain of the Department of Defense should be presented to the Commission on Armed Services of the Senate and House of Representatives." The law states that the report must address at least the following issues:

1. An analysis of the current availability and a national and global forecast in the field of rare earth elements used in defense systems, including the analysis of the estimated availability of these materials on the export market.
2. An analysis of the actions and events outside the control of the U.S. government, which could limit DoD access to REE, such as prior public acquisitions and the attempt of acquisitions of the REE mines and exploitation rights of these minerals.
3. An identification of the defense systems which are currently or could be dependent on REE, and whose supply could be limited by actions and events identified above or actions and other events outside the control of the U.S.

[7] ***, *It's official: Fed required to report to Congress on rare earth in the US Defense Supply Chain,* Industry News, Nov 1, 2009.

4. Any actions which the DoD made or intends to make to address any kind of risk to national security.
5. Similar recommendations for further action to address the issues covered by the report.

The republican Mike Coffman commented on the situation from May 2011: “The Department of Defense is facing a strategic shortage of “rare earth elements” in the short term and the materials necessary to support our armed defense systems based on rare earth elements are especially at a critical level”.

Peter C. Dent, vice president for business development with Electron Energy in Landisville (Pennsylvania, USA), a company which produces electronic components that require REE said: “In 1970, we were one of the first companies in the world producing magnets from REE. In the late 1980s and early 1990s, the American industry based on REE reached its peak with over 20 companies that used rare earth elements. Then during the 1990s we started the decline and the migration of this industry to China. Now my company is the last producer of magnets from REE in America”.[8]

Today, the United States doesn’t use in the production magnets, neodymium, boron rare earths of iron, but they are still found in our precision guided munitions, ships, aircrafts and other weapons systems."

[8] Mitch Jacoby and Jessie Jiang, eds., *Securing The Supply Of Rare Earths. Green-energy and high-tech industries grow anxious over China's monopoly on these valuable resources,* volume 88, Number 35, August 30, 2010 pp. 9-12 (selective).

CONCLUSIONS

Today, rare earth elements represent a geopolitical defiance on behalf of the country or the countries that have rare earth elements deposits, identified and exploitable with the current technologies. Béatrice Héraud calls the REEs “the vitamins” of the new technologies[1].

The group of 17 minerals called rare earth elements, which have similar chemical and electromagnetic properties serve, as we saw in this paper, to manufacture various displays for the Information Technology and Communication industry, audio systems, cameras, essential parts of the new hybrid cars - motors and batteries. The engines of classic cars consume gasoline, diesel or refined alcohol and the motor of hybrid cars uses electricity stored in the battery.

So, we use today rare earth elements for the high-tech production of durable magnets, used for the operation of wind turbines, the batteries of hybrid cars, mobile phones and computers. The problem in the field of REEs is the increasing demand registered in the last decade, from 40.000 tons to over 120,000 tons, by most authors. In 2010, as an experiment, China temporarily operated a massive cut in the export of REEs. Now, only China's exports or REEs are approximately 30.000 tons per year, a quarter of what the world needs. The interruption of the Chinese supply of these “critical metals” extracted from REEs would have affected the military capabilities of the developed countries to produce high-tech weapons, but no one has commented on this case, since it is of strategic importance. The presence of competitive supply chains and the stocks of these “critical metals”, created at a global level eliminated apparently this vulnerability.

In order to apply more “green” technologies, if we follow the forecasts, the world would need about 200,000 tons of rare earth elements by 2014. But, if the future no.1 economy in the world, China, completely abandons its exports during these hard years for the world economy, what is going to happen? Does the world economy still work on the principle of free market economy? Obviously not! Our answer is that

[1] Béatrice Héraud, *Terres rares: l'enjeu du recyclage*, URL: www.novethic.com, visited on the 4th of april 2011

without the new "green" technologies and free access to REEs, the world economy will further complicate its already complicated existence.

Of course, the countries of the world see Chinese attitude regarding the REEs as a threat. In order to put an end to this global economic crisis, they rely on high technologies, which in turn require rare earth elements. China also has the same goal, trying to shift the economy to achieve a higher added value. Chinese rare earth elements are a major strength in its power strategy and it uses this especially against Japan, with whom it has a quasi-permanent maritime and territorial conflict.

After the political crisis and tension between the two countries in the spring of 2012, based on a drastic limitation of Chinese rare earth exports, China has blocked the exports of many products to the Japanese archipelago, including rare earth elements, the Japanese industry being highly dependent on that.

Conventional wisdom tells us that the Asian giant China will continue in the future to carefully manage the production of rare metals, obtained from REEs and to reduce the exports in order to create those downstream REEs industries and jobs. Global demand for the products made of rare earth elements is expected to grow at a double-digit rate. Already the world's largest market for cars and wind turbines based on rare earth elements, which is China, will continue to consume a growing percentage of its production of REEs. China consumes now 80 percent of its own REEs production.

The Korean government announced that it had created the Korean Institute for Industrial Technology (KITECH), in part to address the issues related to rare earths, essential for the nation's industries, high-tech and green. The President of KITECH, Na Kyoung Hoan said that 257 billion dollars will be spent over the next nine years to provide and refine rare metals in Korea.

Rare earth elements are becoming increasingly popular worldwide. But nothing can ensure that what is discovered today could turn into production tomorrow. In the 1970s, researchers and scientists thought that poly metallic nodules, these "rocks" extremely rich in minerals, which could be found everywhere in the seabed, would become an energy source of the future. The forecasts regarding poly metallic nodules found in impressive quantities in the seabed changed because the investments for extracting it were not economic, without the necessary technology. The situation shouldn't repeat when it comes to the impressive rare earth elements deposits discovered in 2011 by the

Japanese researchers on the bottom of the Pacific Ocean, off the coast of Japan. According to the estimates already made, the seabed of the Pacific contains huge reserves of rare earth elements, about 1,000 times higher than the surface ones.

The economic present and future of the world depend more and more on the metals extracted from REEs which form the basis of a much diversified production of economic goods, from electric motors to solar panels and computer parts. In 2010-2011, the global economic crisis hit also the non-energetic raw material supply[2].

Rare earths are used to produce a long list of electronic devices - ranging from wind turbines to flat screen TVs, from most consumer electronics to economic goods related to green energy. The rare earth elements include minerals such as dysprosium, terbium, thulium, yttrium, lutetium, which have applications in electronics, aviation, atomic energy, aeronautics and space research. Rare earths are used in technology for the fabrication of wind turbine generators and motors, electric vehicles and their electric batteries, fuel cells and energy efficient lighting.

[2] URL: www.naturalnews.com/028028_rare_earth_elements_mining.htmlvisited on the 28th of May 2010

Annexes and Tables

Annex no. 1

Opinions on the economy of REE

The demand for REE will exceed the supply if mankind decided to seriously turn towards the green technologies. In that case the big producers won`t be able to meet that demand.

John Kaiser, California, USA, mining expert with 25 years of experience in the industry of REE.

The Japanese are dependent on REE. Without it they can`t survive.

An Si Hu, with the Committee of high-tech REE Zone in Baotau.

The new export quotas are appropriate and necessary. The reality is that REE were so far cheap and they were commercialized randomly. As Russians benefit from their gas reserves, which supplies most of the European Union, so China currently controls the global reserves of REE. However, at least one third of REE deposits could be found outside China. The other countries should operate their own resources. China has already supplied the world over 90 percent of its REE production. We need the REE left for ourselves.

The speaker of the Chinese Government in a press conference in March 2010.

This fact (the discovery of important REE deposits) will represent the backbone of the Afghan economy.

Jalil Jumriany, counselor to the minister of mining in Afghanistan

Annex no. 2

Romanian Research Projects in the field of REE

- Professor Kappel Wilhelm[1], Ph.D., Ph. D. thesis: Study of the magnetic behavior of some rare-earths based ternary compounds" (1999 Babes-Bolyai University from Cluj-Napoca, Faculty of Physics);
- 25 August-2 September 1999, French-Romanian Summer School "High performances permanent magnets", Cluj-Napoca, Romania, organized by Universite de Sud – Paris, Universite Joseph Fourier – Grenoble, CNRS – Grenoble, Babes-Bolyai University – Cluj-Napoca.
- *Composite magnetic materials with imposed technical and functional requirements, RELANSIN Project - 718/2001, developed between 2001 and 2004;*
- *Fe-Cu composite anisotropic permanent magnet (COMPOMAG), Project MATNANTECH, conducted between 2003 and 2005*;
- Codescu Mirela Maria, PhD, PhD Thesis: "Studies and experimental research concerning the processing and characterization of new hard magnetic alloys based on transition metals and rare-earths elements", Politehnica University of Bucharest, 2003);
- The study of compounds with molecular magnetism, CERES project, conducted between 2004 and 2006;
- Intelligent materials of Fe-Cu for equipment designed to avoid accidents in nuclear power plants (MIDAC) Security project conducted between 2005 and 2006;
- Prof. Murariu Titus, PhD., The geochemistry of rare earth elements and radioactive metals in the Romania`s pegmatite. Grant type A, code CNCSIS 1399, Contract no. 2607, 2005 - 2006.
- Anisotropic nanocomposite for permanent magnets of very strong specific magnetic energy (NANOMAG) CEEX project, conducted between 2005 and 2008.
- Sintered magnets based on Nd-Fe-B alloys with high thermal stability (MAGSTAB) Project INVENT no. 4197/2005, held between 2005 and 2006;

[1] este primul specialist român în fizica pământurilor rare

- Temperature Stability and Corrosion Resistance of Rare Earth Magnets Transition Metals, INCO Copernicus project no. ERBIC 15CT 96-0758, held from 1977 to 1999;
- Characterization of industrial and magnetic steel, INCO Copernicus Project, no. Herbicide 15CT 96-0817, held in 1999;
- Grant type A, The geochemistry of rare earth elements and radioactive metals in Romania`s pegmatite. CNCSIS Code 1399, Contract no. 2607, 2005-2006. Director: prof. PhD. Murariu Titus;
- Murariu, T., Raileanu, M. (2006). Rare alkali metal lithium from granitic pegmatite - I metallogenetic indicator for the rare elements, Bucharest, Rom. Journ. of Mineralogy, vol. 82, 2006;
- Gheorghe Cristina Petre, Ph.D. thesis: Composition and structure effects in rare earth ions emission in crystals and ceramics, University of Bucharest, 2008.

Annex no. 3

International contribution of Romanian scientists in the field of REE

- Prof. Codescu Mirela-Maria, Ph.D., The 49th World Exhibition of Innovation, Research and New Technology, EUREKA, Bruxelles, 2000, Award: Gold Medal for patent: "Preparation method for NdFeB fine powders";
- Prof. Codescu Mirela-Maria, Ph.D. Award: Bronze medal at Inventions Exhibition Geneva (2002) for patent: Preparation method of bonded magnets, using organic binder".
- Prof. Codescu Mirela-Maria, Ph.D. Award: Bronze medal at Inventions Exhibition Geneva (2001) for patent: “Bearing with magnetic bilateral sustentation after the axial direction”.

Annex no. 4

Note of reading

Alexandre Drier de Laforte

It refers to the study "Terres Rares" by Vasily Aksyonov Editions Actes Sud; 5 January 2009; Translated from Russian by Lily Denis; ISBN: 978-2-7427-8043-3

Stratov Guen is one of the Russian multibillionaires, ex-leader of the young communist organization, Komsomol, of ex-USSR. He manages, together with Achka Stratova, his wife, a legendary Slavic beauty, the company "Table M.", a multinational specialized in operating REE (lanthanide plus scandium and yttrium).

Guen and Achka are seconded by Gouram Iasnochvili, a fearless Georgian of mordant irony.

Among the main characters of the novel there are Ranis Anchor Jaromchoba Skov, "the communist king" of Gabon, Master Souk and Master Chok two bodyguards useful and of unwavering loyalty. Of equal importance in the "economy" of the novel there are Maxime Almazov, former clerk of "Table M"`s competitor, and Nik Orizon, an English teenager of 13 years old, who plays the piano and participate in international surf contests and quotes Russian writers ...

These are the characters of the novel - "Terres Rares" ("Rare Earths"), written by Vasily Aksyonov in his villa in Biarritz.

They can be found also in his previous novels "Confrères" ("*Colleagues*"), "Une saga Moscow" ("*Moscow ow ow*") and "À la Voltaire" ("*Voltairian Men and Women* "). All these actors see their own destinies unfolding in "Rare Earths" to converge to Aksyonov's exuberant imagination, who shares with Bulgakov the taste for movement and irrelevance.

The story of "Rare Earths" begins with Guen and Achka conceiving their two children in a volcano crater, rich in rare minerals, in Gabon. Then the plot unfolds in the political sphere. Aksyonov`s virtuosity reaches the peak when he describes the Atlantic beaches, Africa presented as the mother of all species and the plains of Siberia. The depth of the "Reservoir", the nickname given to the Atlantic Ocean has no equal than the human spirit. The most striking scene of the novel develops this metaphor, and the author wonders about the fate of modern people and being caught between their desire for freedom and the ideological boundaries of history.

Table 1
REE applications

Light REE (more abundant)	Main Application	Heavy REE (less abundant)	Main Applications
Lanthanum	Hybrid motors, various alloys	*Terbium*	Permanent magnets
Cerium	Catalyzer, metal alloys	*Dysprosium*	Permanent magnets, hybrid motors
Praseodymium	Magnets	*Erbium*	lighting
Neodymium	Catalyst in oil refinery, hard disks, headphones, hybrid motors	*Yttrium*	Red color, lamps fluorescent, ceramics, alloy agent
Samarium	Magnets	*Holmium*	Glass color, lasers
Europium	Red color for TV and computer displays	*Thulium*	X Ray units for Hospitals
Gadolinium	Magnets	*Lutetium*	Catalyst in oil refinery
		Ytterbium	Lasers, steel alloys

Source: U.S. Geological Survey, Circular 930-N, US Congressional Research, sept. 2010

Table 2
World production by country (in tons of REE oxides)

Country	1988	1999	1990	1995	2000	2004	2008
United States	11.533	20.787	22.713	22.200	5.000	...	...
China	29.640	25.220	16.480	25.000	73.000	98.000	125.000
Australia	6.530	7.400	7.975	...	...	...	...
USSR / CIS	...	...	...	6.000	2.000	...	...
India	2.200	2.200	2.475	2.700	2.700	2.700	2.700
Kirgizstan	...	...	...	...	16.536	...	...
Brazil	1.690	1.900	1.100	400	...	402	550
Malaysia	1.630	1.646	1.925	448	450	250	380
Thailand	375	365	358	...	...	...	...
Sri Lanka	110	110	110	120	120	...	...
Canada	100	100	...	...	...	...	...
Zaire	92	96	94	11	...	...	...
Total	53.900	59.824	53.230	56.900	83.300	101.000	129.000

Source: Mineral Yearbooks 1990-2008, US Geological Survey

Table 3
China`s REE exports (in tons)

	2005	2006	2007	2008	2009	2010
Export quota		62.000	60.000	47.449	50.145	30.258
Scandium, yttrium	12.986	13.677	12.458	6.961	5.345	...
REE and metals	52.220	52.732	41.894	48.024	38.573	39.813

Source: COMTRADE, UN Statistics Division (2005-2009); China Customs Statistics, in Mining weekly (2010), Trade Ministry (cited in Beijing Review, 21 January 2011)

Table 4
Critical raw materials for the EU

Antimony	Indium
Beryllium	Magnesium
Cobalt	Niobium
Fluorite	**REE**
Gallium	Platinum
Germanium	Tantalum
Graphite	Wolfram

Source: Critical raw materials for the EU, European Commission DG Enterprise and Industry, 30 July 2010

SELECTIVE BIBLIOGRAPHY

1. ***, *Avatar pe Terra: pământurile rare sunt seva civilizației*, pe site-ul www.descopera.ro, 16 martie 2010
2. Avram N. M.; Pop, V. şi Tetean R. (editori), *New trends in advanced materials*, Editura Universității de Vest, Timişoara, 2005, capitolul "Magnetic Nanocomposites based on NdFeB", autori: W. Kappel, M. M. Codescu, J. Pintea şi N. Stancu, ISBN 973–7608–41–0
3. Bradsher, Keith, *China Tightens Grip on Rare Minerals*, în The New York Times, August 31, 2009
4. Bradsher, Keith, *Earth-Friendly Elements. Mined Destructively*, în The New York Times, December 25, 2009
5. Buzatu, Adrian, *Tehnologiile moderne au nevoie de pământuri rare, iar ele sunt ... rare*, pe site-ul www.stiintaazi.ro, 21 martie 2010
6. ***, *Concern as China clamps down on rare earth exports,* The Independent, UK news site
7. Chen Deming, *La Chine etudie le recyclage et la substitution des terres rarea,* sur le Quotidien du peuple, pe site-ul http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo1185.html, vizitat pe 18 iulie 2012
8. ***, *China defends its policy on rare earth export control*, Communiquee gov., 29 août 2010
9. ***, *China does not have monopoly on rare earth,* Caijing Guojia Zhoukan, 31 octobre 2010
10. ***, *China leader answer questions on currency, relations with US,* Wall Street Journal, 17 janvier 2011
11. ***, *Chinese expert calls for immediate stockpiling*, Metal Pages, 2 novembre 2009
12. Custers, Raf, *Terres rares, enjeu de développement*, pe site-ul http://www.alliancesud.ch/fr/documentation/dossiers/matieres-premieres/terres-rares, vizitat pe 28 iulie 2012, orele 14,51
13. Dobrescu, Emilian M., *Un zăcământ de pământuri rare va schimba soarta războiului din Afganistan,* în Financiarul, 17 august 2010
14. Dobrescu, Emilian M., *Rare Lands Economy. A New Branch of Economic Sciences*, în Business & Leadership, nr. 1, 2010, pp. 31-52

15. Dobrescu, Emilian M., Pământurile rare. Noi aşteptări, în
16. Dominique, Albertini, *Les terres rares, un élément majeur de la puissance chinoise*, în Liberation, 14 mars 201
17. Jacoby, Mitch and Jiang, Jessie, eds., *Securing The Supply Of Rare Earths. Green-energy and high-tech industries grow anxious over China's monopoly on these valuable resources*, volume 88, Number 35, August 30, 2010 pp. 9-12
18. Жеру, М. И., Отчет по теме: Изучение основных вопросов петрологии и геохимии докембрия Среднего Приднестровья с целью обеспечения поисков руд редких и цветных металлов, а также высокоглиноземистого сырья, Fondurile Academiei de Ştiințe a Moldovei, 1966
19. ***, *Grandes manoeuvres autour des metaux rares,* în Le Monde, 3 février 2010
20. Gorman, Steve, *As hybrid cars gobble rare metals, shortage looms,* Reuters, aug 31, 2009
21. Gupta, C. K. şi Krishnamurthy N., *Extractive Metallurgy of Rare Earths,* CRC Press, 2005
22. Haiduc, Simona, *China controlează azi cea mai mare parte din producția globală de metale rare,* în Financiarul, 22 iunie 2010, p. 10
23. Hedrick, James B., *Rare Earths*. USGS Minerals Yearsbook, 2004
24. Héraud, Béatrice, *Terres rares: l'enjeu du recyclage*, pe site-ul www.novethic.com, vizitat pe 4 aprilie 2011
25. Homans, Charles, *Sunt rare pe Terra pământurile rare?,* în Foreign Policy, 15 iunie 2010, pe site-ul www.Foreign Policy, vizitat pe 19 septembrie 2010
26. ***, *It's official: Fed required to report to Congress on rare earth in the US Defense Supply Chain,* Industry News, Nov 1, 2009
27. Kappel, W. şi colab., *Evaluation of the Corrosion Behavior of the Permanent Magnets based on Rare Earths, used in Aeronautical Industry*, Journal of Optoelectronics and Advanced Materials, vol. 8 , nr. 2, 2006, p. 523- 526, ISSN 1454-4164
28. Krebs, Robert E., *Dysprosium. The History and Use of our Earth's Chemical Elements*. Greenwood Press. 1998, pp. 234–235
29. ***, *La Chine autorise des quotas supplémentaires d'exportation de terres rares*, în Liberation, 17 mai 2012
30. ***, *Lanthanides et terres rares,* pe site-ul www.larousse.fr/ encycopedie, vizitat pe 20 iulie 2012, orele 21,28

31. Лвина, Д. А. Отчет по теме: Закономерности распределения цветных, редких и редкоземельных элементов в докембрийских образованиях Севера Молдавии, Fondurile AGeoM, 1972
32. Macqueron, Grégoire, *Des terres rares en abondance pour les technologies vertes?*, pe site-ul www.Futura-Science.com, vizitat pe 19 iulie 2012, orele 8,15
33. ***, *Matieres premieres: defaite chinoise devant l'OMC*, în La Tribune, 28 decembre 2009
34. Милованов, Г.Н., Черносвитов, Ю.Л., *Редкоземельные элементы,* Госгеолтехиздат. Москва, 1959
35. ***, *Mongolie: les terres rares empoisonnent l'environnement*, pe site-ul http://www.novethic.fr/novethic/planete/environnement/pollution/mongolie_terres_rares_empoisonnent_environnement/132199.jsp, vizitat pe 19 iulie 2012, orele 5, 19
36. Nakao, Yuriko, *Des terres de moins en moins rares,* Reuters, 6 juillet 2011
37. Naumov, A. V., *Review of the World Market of Rare Earth Metals*, în Russian Journal of Non-Ferrous Metals, nr. 49, 2008, pp. 14–22
38. Pambrun, Stéphane, *A Pékin, on ne badine pas avec ce nouvel Eldorado*, pe site-ul www.novethic.com, vizitat pe 4 mai 2010
39. Pop, Iuliu, *Magnetismul pământurilor rare*, Bucureşti, Editura Academiei Republicii Socialiste România, 1968
40. Popuiac A., Aspecte generale din geochimia pământurilor rare din nord-estul Republicii Moldova, în Buletinul Institutului de Geologie şi Seismologie al Academiei de Ştiinţe a Moldovei, nr. 1, 2009, p. 29-40
41. ***, *Position Paper. Chinese Activities in Eastern Europe. Success through market-aggressive financing offers,* Ost-Ausschuss des Deutschen Wirtschaft, BDI, octobre 2010
42. ***, *Rare Earth Elements. Critical Resources for High Technology*, USGS Fact Sheet 087-02, 2002
43. Roux-Goeken Victor, *Terres rares: « un paradoxe entre le procédé d'obtention polluant et leurs applications environnementales », entretien avec Christian Hocquard, économiste des matières premières au BRGM,* pe site-urile www.Actu-Environnement.com, 2 iunie 2010 şi www.interview-christian-hocquard-terres-rares-applications-environnementales-impact-chine-10352.php4.htm, vizitate în ziua de 27 septembrie 2010
44. Scala, Bruno, *Des terres rares au fond du Pacifique,* pe site-ul www.Futura-Siences.com, vizitat pe 19 iulie 2012, orele 20,48

45. Stănculescu, Oana Maria, *China's Rare Earts TradeAnalysis*, în Anuarul Institutului „Gheroghe Zane" din Iaşi, ton 20, 2011, pp.133-139
46. Stoica, Mihaela, *Americanii au făcut o descoperire uriaşă în Afganistan: minereuri în valoare de circa un trilion de dolari*, în Adevărul, 14 iunie 2010
47. Swain, Frank, *How to remove a finger with two super magnets,* Media Group LLC, March 6, 2009, pe site-ul http://scienceblogs.com/sciencepunk/2009.php, vizitat pe 6 iunie 2010
48. ***, *Terres rares, un enjeu stratégique,* în Le Monde Diplomatique, 15 mars 2012
49. Truchot, Paul, *Les terres rares: mineralogie, proprietes. Analyse,* Paris, G. Carre şi C. Naud, 1898
50. Walet, Leonora, *Asia Green Investment Correspondent, Rare earts crucial in drive for green gadgets,* corespondență Reuters de la Hong Kong, 12 august 2010