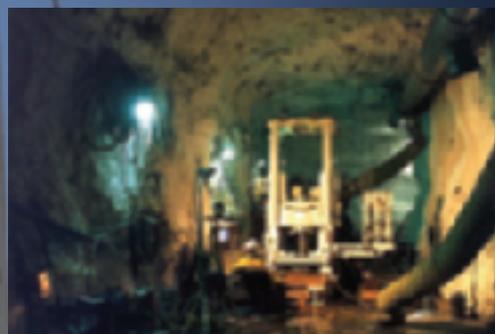


International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle

22–26 June 2009, Vienna, Austria



**Exploration, Mining,
Production, Supply
and Demand,
Economics and
Environmental
Issues**



**BOOK OF
ABSTRACTS**

URAM-2009



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International Atomic Energy Agency

Atoms for Peace

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Opening Session

Address of Symposium President:

The Uranium World in Transition from Stagnancy to Revival

Franz J. Dahlkamp

Welcome everybody to this international multidisciplinary symposium on the uranium raw materials cycle. Let me begin by expressing my gratitude to the IAEA authorities, today represented by the Deputy Director General Dr. Y. A. Sokolov, for initiating this conference, and providing the facilities and services.

Dr. C. Ganguly and Dr. J. Slezak also deserve special mention and thanks since they conceived the multidisciplinary program and, together with their co-workers, organized it and put it into action. And as the agenda shows, the spectrum of topics covered this week is indeed broad, ranging from exploration to mining and milling through to environmental, socio-economic and regulatory aspects. Besides providing an update on the state of the uranium industry today, this multidisciplinary approach pursues two additional goals.

- First; to provide an indication of the wealth of information contained in numerous publications covering past and present uranium research, exploration and recovery concepts, techniques etc., and
- Second; to facilitate communication, not only between the representatives of the various disciplines actively engaged in the uranium raw materials cycle, but also between professionals and the public.

With Respect to the little-known wealth of previously published information:

After the decline of the uranium industry in the 1980s, exploration and mining activities fell dormant for almost a quarter century prior to the revival in the first decade of the 21st century. During that quiet interval, the uranium sector lost many well-trained, experienced and knowledgeable geologists as well as mining and metallurgical engineers. As a consequence, during the ongoing revival, the industry suffers from a lack of staff with depth in uranium-specific knowledge.

As traditional internal company education was largely abandoned – except by a few large corporations that kept their most experienced staff as tutors and mentors for younger trainees, most newcomers had (and still have) to educate themselves, which is not an easy task, especially without mentors.

To quote Thomas Alva Edison, - there are three ways to achieve education:

- (a) by learning/studying, which is the hardest way, requiring patience and endurance,
- (b) by copying, which may be the easiest mode but which is subject to the caprice of fortune, and
- (c) by experience, which represents often the most unnerving or demoralizing and costly mode.

Due to the lack of mentor- and tutorship on one side and lack of patience, ignorance and/or understanding on the other, the younger generation – with few exceptions – tends to perform their duties and solve related problems by their own means without taking the, admittedly, often boring search for and study of relevant literature; in other words, they practically invest their time in trying to re-invent the wheel. In doing so they are acting in an inefficient and costly fashion. Indeed, the search for appropriate literature references has become an arduous task caused by the numerous publications on uranium subjects; but not only that, the content of papers is highly mixed in quality.

The organizers of this symposium hope, therefore, that presentations and discussions this week will provide those interested with sources of pertinent information and that all papers presented will include comprehensive bibliography with adequate accuracy.

With respect to facilitating communication:

There are examples showing that incomplete communication between the various disciplines involved in uranium projects can result in misunderstanding and misinterpretation of data. As this may result in the failure of a project, open communication across disciplinary boundaries needs to be maintained and encouraged at all times.

Not considering emotion-based staff-internal rivalry, clashes of personalities and competing characters fighting for priority of their concepts or methods, different ways of resolving issues and developing solutions are typically the result of profession-specific upbringing and working logic. And even though members of all technical disciplines involved in the uranium cycle may be speaking the same language and may be using the same professional terminology, misunderstanding or misinterpretation of documents and data is common.

A historical case may serve as an example: The exploration department of a mining company has compiled all relevant data of a discovered U deposit hosted in Precambrian rocks in comprehensive reports, maps and tables.

What did the mining department do? Neglecting the distribution of ore properties, the pit was designed in agreement with topographic requirements.

How did the metallurgical department use the deposit documentation? It decided to install autogenous grinders for ore crushing under the assumption that Precambrian rocks are hard and massive. And, by assuming an ore with an average carbonate content of about 3 %, it implemented an acid leach process.

After the first truck loads of ore had been treated, the process engineers complained that

- (a) the grinding technique does not function due to too much argillaceous ore components and that
- (b) the acid consumption exceeds by far the calculated amount. Subsequent analyses of the ore treated showed a carbonate content of some 8-9 %.

What were the reasons for these difficulties? Simply put, the mill designers had ignored the petrographic-mineralogical description of the ore and the miners had ignored in their open pit design the heterogeneous carbonate distribution in the deposit.

A scape-goat was quickly found: the geological department, but only for a short while. The geologists could easily show that all features of the deposit were properly documented but were not taken into consideration by the engineers. Clearly, a proper exchange and mutual check of data interpretation by the three departments would have avoided the unpleasant experience.

In order to help to overcome or at least to reduce such interdepartmental communication breakdowns, everybody in this symposium is encouraged not only to attend his profession-specific presentations but also those of the other specialists.

With respect to Environmental, socio-economic and public relations aspects

Last but certainly not least, in these times not only economic conditions but also environmental, socio-economic and social licenses to mine an ore deposit are required, hence trans-disciplinary communication should also be an obligation in the following areas:

Environmental surveys: Underdeveloped co-ordination of geochemical surveys during the exploration stage with environmental studies has been noted. Soil sampling and collecting samples for certain environmental studies could easily and cost-efficiently be combined if both parties are capable and willing to co-ordinate their programs.

Socio-economic aspects: Indigenous people like Inuit, Papuas, or Aborigines have historically and culturally a different lifestyles and attitudes toward development, compared to people of industrialized nations. Developing cross-cultural understanding and communication skills should be included in standard training programs for company personnel destined to work in regions with indigenous people.

Public relations: Individuals working in the uranium industry are at times asked to respond to critical questions from the public, that are not necessarily friendly in nature. How does one best react to these questions, in particular to those of anti-nuke al-gore-rythms? The tried and true way is still to respond with facts. This, of course, requires the capability to respond in a simple, accurate and understandable way what one is doing technically but also how this work complies with environmental and regulatory constraints.

In short: This conference attempts to

- comprehensively describe the state of the industry,
- indicate the wealth of information available as a basis for more efficient work and development of new ideas,
- enhance communication between generations of uranium specialists, separated by a lengthy period of stagnation in the industry,
- open lines of communication to facilitate understanding between the professional factions and, finally
- provide guidance on how to communicate efficiently and tactfully with the public, arguably the industry's most important stakeholder.

IAEA activities on uranium resources and production and databases for the nuclear fuel cycle

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Natural uranium (~99.3% U-238+ ~ 0.7 % U-235) is the basic raw material for nuclear fuel. The present generation of nuclear power reactors derive energy from the ‘fission’ of U-235, the only ‘fissile’ isotope in nature. These reactors also transmute the more abundant U-238 to man-made fissile isotope Pu-239, which could be subjected to multiple recycling, as fuel, in fast reactor for efficient utilization of natural uranium resources and to ensure long term sustainability of nuclear energy. Uranium is mostly mined and produced in countries without a nuclear power programme. On the other hand, uranium is mostly consumed in countries with nuclear power, but having no uranium. In recent years, rising expectation for nuclear power has led to increase in uranium exploration, mining and ore processing activities all over the world and several new countries, with a limited experience, have embarked on uranium exploration, mining and production. Uranium and its daughter products are radioactivity and health hazardous. Radiological safety is a major challenge in uranium production cycle and in uranium mine and mill remediation and reclamation. Another specific challenge being faced currently by uranium raw material industry is the retired or ageing manpower and lack of experienced staff around the world.

The IAEA’s programme on ‘Uranium Resources and Production and Databases for the Nuclear Fuel Cycle’ encompass all aspects of uranium geology and deposits, exploration, resources, supply and demand, uranium mining and processing, environmental issues related to uranium production cycle and databases for uranium fuel cycle. The IAEA collaborates with OECD/NEA in producing an authoritative and updated document on uranium resources, production and demand, popularly known as Red Book, which is published biennially by OECD/NEA. As a spin-off from uranium resources activities, two reports titled, ‘Analysis of Uranium to 2060’ and ‘Red Book Retrospective – Country Reports’ are being prepared. In addition, the IAEA maintains and updates on-line database on worldwide uranium deposits (UDEPO) and a data base on uranium mines and mills under Nuclear Fuel Cycle Information System (NFCIS). In the area of uranium exploration and production cycle, IAEA organizes training programmes, workshops and technical meetings to promote good practices in uranium production cycle and environmental protection. Recently, the IAEA has revived the programme on Uranium Production Site Appraisal Team (UPSAT) to assist member states to improve the operational and safety performance of uranium production facilities. This tool can be used by Members States to check and improve their approaches in applying good practice in uranium production.

The present paper summarizes IAEA’s ongoing activities and planned programme for the budget cycle 2010-2011, highlighting the uranium resource, supply and demand, databases, the training programmes, technical meetings and Technical Co-operation (TC) projects on uranium exploration, mining and ore processing and good practices in uranium production, including UPSAT.

A long-term view of uranium supply and demand

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The *Nuclear Energy Outlook*, issued in October 2008 on the 50th anniversary of the OECD Nuclear Energy Agency (NEA), responds to the renewed interest in nuclear power. In 2008 the International Energy Agency (IEA) projected that, with current government policies, total primary energy and electricity demand will increase respectively by more than 50% and 90% by 2030, and that the great majority of this increase will be met by fossil fuel sources, even though global climate change and security of energy supply remain key issues.

Nuclear energy is an established technology offering a reliable option to address these issues. More efficient use of energy, renewable sources, and carbon capture and storage are important components of the response to these key issues, but no option should be overlooked. Nuclear energy is part of the solution; the size of its contribution will depend as much on the capabilities of governments and the nuclear industry to address society's concerns about safety, waste disposal and proliferation concerns, as it will on its economic competitiveness. In 2008, installed nuclear generating capacity of around 372 GWe and annual production of some 2 700 TWh supplied about 16% of the world's electricity. Using authoritative electricity demand estimates for 2030 and 2050, the NEA elaborated its own scenarios of nuclear energy development. Designed to illustrate possible future contributions of nuclear energy to global supply the outcome is a range of 4 300 to 10 500 TWh worldwide in 2050.

Although the Nuclear Energy Outlook explores a wide range of issues surrounding the use of nuclear energy, this presentation will focus on the supply of uranium required to support nuclear energy expansion as projected by the NEA. Natural uranium resources are widely distributed around the world, including in key countries where geopolitical risks are limited. Its cost represents only a few per cent of the total cost of generating electricity at nuclear power plants and therefore uranium price volatility is not as major a concern for nuclear power plant owners and operators as it is for fossil fuel alternatives. Maintaining strategic stockpiles representing several years' consumption is also relatively easy and economic.

World identified uranium resources (5.45 million tU at US\$130/kg U, or US\$50/lb U₃O₈) are adequate to meet projected future high case nuclear power requirements until 2050, providing that mine production is increased significantly. Supplying uranium requirements beyond this date will require the identification of additional resources. However, recent financial market turmoil and declining uranium spot prices, the opaque nature of the uranium market, increased regulatory requirements, scarce specialized labour and fluctuating costs of raw materials makes the process developing mines, already demanding significant amounts of time, expertise and expenditures, increasingly more challenging. Considerable effort will be required to bring about the substantial increase in mine production required to meet future NEA demand projections. In addition to these challenges, uranium producers must continue developing and implementing best practices globally in order to improve public perception of uranium mining. Doing so will be necessary to develop currently identified resources to their full potential as well as to expand the existing resource base.

Uranium Markets & Economics

Nuclear power has a bright outlook and information on uranium resources is our duty

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Because of its growth in number and in its average development level, and besides food supply, Human kind is facing three main challenges, water supply, energy supply and climate change. Nuclear power is not relevant to address all in the same proportion, however it may help addressing all of them.

Therefore the question of uranium supply and more generally of resource sustainability is increasingly important.

It is the kind of question drawing a complex blending of knowledge, hopes, dreams, mistakes and disinformation amongst pro-nuclear, anti, various stakeholders and of course the general public.

Beyond the quality of the available information, beyond hard facts, beyond all the technicalities, it is essential to deliver a message that is easy to understand, that does reflect the real knowledge and properly identifies the unknowns.

Another point is the question of the environmental impact of uranium mining. Again, properly recalling what was done, what has been achieved and what is planned will help to improve its general acceptance.

These two topics are critical to a successful contribution of nuclear power to the challenges we are collectively facing.

The economic production of uranium at the pace of nuclear power plants, i.e. in the long term, requires not only well run mining operations, but also the adequate level of information to reassure investors. This should come along with an adequate level of environmental protection to reassure the stakeholders while keeping the related expenses at a sound level.

The uranium exploration, mining and environmental community has the duty to timely and effectively address all these points.

Uranium Stewardship – the unifying foundation

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Uranium Stewardship is a WNA programme of action seeking to define, and achieve worldwide industry adherence to, principles and practices designed to ensure that uranium and its by-products are managed in ways that are safe, environmentally responsible, and economically and socially acceptable.

Through this programme WNA will engage all industry sectors involved with the uranium life cycle, as well as relevant stakeholders, with the objective of first encouraging best practice, then sustaining an ongoing industry effort to continually improve it.

In pursuing this objective WNA has identified key Principles of Uranium Stewardship and will aim to obtain, from all relevant enterprises, formal commitment to a Code of Practice that translates these principles into worldwide industry performance.

The WNA sets forth these Principles of Uranium Stewardship as the basis for a Code of Practice, to which relevant enterprises are invited to commit and adhere:

1. Support the safe and peaceful use of nuclear technology.
2. Act responsibly in all areas we manage and control.
3. Operate ethically with sound corporate governance.
4. Uphold and respect fundamental human rights.
5. Contribute to the social and economic development of regions where we operate.
6. Provide for responsible sourcing, use and disposition of uranium and its by-products.
7. Support best practice and responsible behaviour throughout the nuclear fuel cycle.
8. Improve continually in all areas of our performance.
9. Communicate regularly on progress.
10. Review and update.

The Australian Uranium Association's *Uranium Stewardship Principles* reflect and are consistent with the global principles being developed under the auspices of the World Nuclear Association.

The Association's *Principles* are additional to the broader Australian minerals industry's commitment to sustainable development as outlined in the Minerals Council of Australia's *Enduring Value*; and to the Australian Uranium Association's *Charter* and *Code of Practice*.

Through the *Principles*, the Australian uranium industry aims to engage the public and earn trust for the exploration, mining and export of uranium.

Safeguards obligations related to uranium/thorium mining and processing

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As the interest in nuclear energy has started to rise, the demand for uranium and thorium resources is expected to increase for the foreseeable future. This is already seen from the high number of new uranium prospecting projects reported in the news, and it is anticipated that the amount of uranium (and thorium) recovered from both conventional and unconventional resources at existing and new mines and ore processing facilities is going to grow significantly. The increasing number of mines and countries involved in uranium (and thorium) mining, as well as the expected increase in the number of countries operating nuclear power plants, predicts a significant increase in the trade, export and import of nuclear material and uranium/thorium bearing resources. In this context, the purpose of this paper is to raise the awareness of the uranium/thorium mining community – regulators, mine and mill operators – to the nuclear non-proliferation concerns involved and to draw their attention to the international safeguards obligations related to uranium and thorium mining and ore processing.

The paper provides an overview of States' obligations under comprehensive safeguards agreements and additional protocols, and explains voluntary reporting schemes designed to provide information to the Agency on uranium and thorium mining and ore processing activities and exports and imports of material containing uranium and thorium. It also discusses how the information provided by States, together with information from open and other sources, are used by the Agency to evaluate States' nuclear activities, and explains how States' cooperation in the implementation of the reporting provisions contributes to the effectiveness and the credibility of the Agency's nuclear safeguards system.

A review of uranium resources, production and exploration in Australia

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As of January 2009, Australia's Reasonably Assured Resources (RAR) recoverable at costs of < US\$80/kg U were estimated to be 1 163 000 t U, an increase of 18% over the previous year. Major additions to resources in 2008 were from Olympic Dam (south east extensions), Ranger 3 and Four Mile. Australia's share of the world's total RAR of uranium recoverable at < US\$80/kg U has increased to about 38% (based on latest world estimates as at January 2007 prepared by OECD-NEA & IAEA).

Australia had an additional 449 000 t U in Inferred Resources recoverable at costs of < US\$80/kg U, mainly in the south eastern part of the Olympic Dam deposit. A number of companies reported Inferred Resources for small calcrete deposits in Western Australia, but most are in high cost categories.

Olympic Dam contains about 30% of the world's total known uranium resources (RAR plus Inferred Resources). Most of Australia's other identified resources are within Ranger, Jabiluka, Koongarra, Kintyre and Yeelirrie. The impacts of higher capital and operating costs on Australia's uranium inventory are discussed.

During 2008; extension of the Beverley lease was approved, allowing development of the southern deposits; Olympic Dam major upgrades to resources and preparation of draft EIS continued; and Four Mile Public Environment Report was released in January 2009. Companies have lodged referrals under the Environment Protection & Biodiversity Conservation Act for development of the following new uranium projects – Crocker Well (SA), Nolans rare-earth phosphate uranium deposit (NT), and Oban field leach trial (SA). BHPBilliton has reported that the company is considering development of the Yeelirrie deposit (WA), and ERA Ltd is proposing a heap leach operation at Ranger.

Australia's uranium production in 2008 amounted to 8 430 t U (9 941 t U₃O₈), which is below 2007 production level of 8 603 t U (10 145 t U₃O₈). Australia remains the world's second largest uranium supplier behind Canada. Kazakhstan is ranked third, but narrowing the gap. Exploration activities continued to focus on established uranium fields.

Paradigmatic shifts in exploration process: The role of industry-academia collaborative research and development in discovering the next generation of uranium ore deposits

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Uranium exploration increased over the past decade in a sympathetic response to a rapid increase in the price of uranium, inspired by fuel supply-demand, and stock market dynamics. Exploration activity likely peaked during this cycle in 2008, with in excess of 850 companies, engaged in the global exploration of a portfolio of over 3000 projects. Global uranium exploration expenditures for the period 2004-2008 are estimated at US\$3.2 billion—from US\$130 million in 2004, to an estimated peak of US\$1.2 billion in 2008. A major focus of the exploration effort has been on brown-fields exploration in historical uranium districts. Less effort has been devoted to exploration at green-field frontiers. An anticipated significant reduction in global exploration expenditures in 2009, and beyond, is anticipated concurrent with the global recession. There is not much evidence to indicate that significant brand-new, large, and higher grade, uranium deposits have been discovered during this uranium exploration cycle. It is likely that future uranium explorers will need to be more efficient, and effective in their efforts, and to adopt new, and innovative business strategies for their survival, and success.

This paper addresses some of the fundamental reasons why major economic discoveries of uranium ore bodies have been elusive over the past two decades, through a cyclical model know as the 'learning curve', using the prolific Athabasca Basin, Saskatchewan, as an exemplar. This model incorporates elements relating exploration expenditure, quantities of discovered uranium, and the sequence of uranium deposit discoveries, to reveal that discovery cycles are epochal in nature, and that they are also intimately related to the development, and deployment of new exploration technologies. The history of uranium exploration is parsed into the early 'prospector' exploration phase (1960-1980), and the current model driven phase (1981-present). The future of successful uranium exploration is envisaged as 'innovation exploration' where a paradigmatic shift in the exploration approach will take the industry towards new discoveries.

Effective engagement within the 'innovation exploration' paradigm will require that exploration organizations adopt industry-academia research, development, and technology transfer as a priority long-term, systematic strategy. Leadership, and management strengths need to be co-opted to bring the academic, and industry team systems together for success, though the use of informational, relational, and reflective learning strategies. Suggestions for several future research avenues within this new paradigm are presented, using the unconformity-related uranium deposit model target as an example.

Uranium markets and economics: Uranium production cost

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The main subject of the report is Equilibrium Price in the uranium market. In the presentation we'll explain what it means, why equilibrium price calculation is so important for the mining sector. We'll also illustrate equilibrium price calculation by providing a real situation in Kazakhstan as the example. If we rank all known deposits according to the level of mining cost and add their potential production output in ascending order of production costs then it will be very easy to see what maximum cost will be required to engage the deposit into operation in order to achieve the required volume of production.

For example, if we need to achieve production output consisting 50 thousands tons we have to put deposit A for operation, but if we need 65 thousand tons U then we have to put the deposit B into operation, where production costs are drastically higher. Let equilibrium price be a price with which it becomes possible to put into operation the deposit with these marginal costs. For the sake of simplicity let's assume that for attracting investments it is quite enough if a price is 30% above the production cost.

What is an equilibrium price of 2009? We have to take into account that it usually takes 7-9 years to put this deposit into operation. Therefore it is necessary to determine uranium demand for 2016-2018, define this marginal deposit and a price with which this marginal deposit becomes attractive for investors. The equilibrium price of 2010 will be different as it will be based on uranium demand of 2017-2019. On the whole, this equilibrium price will be fair from the point of view that uranium producers are not interested in prices higher than equilibrium price as higher market prices will lead to overproduction and sharp fall in prices. The uranium producers are not interested in market prices which are lower than equilibrium price as it will lead to physical shortage of material as that very deposit with marginal cost will not be put into operation in time.

Kazakhstan is able to produce 12 thousand tones of uranium with price \$40-45 per pound, but production of 18 thousand tones with normal expenditures compensation and capital payback requires \$70-75 per pound. Furthermore, additional output expansion requires significant price increase. Under existing prices we have completely hold up from previously planned underground production development in Northern Kazakhstan. Our investments for new in-situ mines development have been suspended. Moreover, previously planned operating mines expansion has also become questionable.

Uranium mining capabilities in the Russian Federation

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ARMZ is the mining arm of the Russian nuclear industry and responsible for uranium supply for Russian nuclear industry. It operates all uranium producing centers in the Russian Federation and has shares in two joint ventures in Kazakhstan.

ARMZ uranium production in 2009 amounted 3 678 tonnes: 3 413 tonnes from three Russian producing centers (3 037 t at Priargunsky, 350 t at Dalur and 26 t at Khiagda) and 114 tonnes at JV Zarechnoe in Kazakhstan. To meet growing Russian nuclear industry requirements ARMZ plans to increase annual uranium production to 10 000 tonnes in 2015 and further to 20 000 tonnes by the year 2025.

Uranium resources of ARMZ enterprises in Russia and Kazakhstan amount 582 663 tonnes and completely meet production plans.

ARMZ also explore opportunities for joint uranium mining in Ukraine and Mongolia, and for uranium exploration in Canada, Armenia, Namibia and other countries.

The principal directions of uranium production development:

- Development of existing and under construction producing centers in the Russian Federation (Priargunsky, Dalur and Kniagda) to the annual production 8 000 t;
- Building three new uranium producing centers Elkon, Gornoe, Olovskaya and other mines based on recently discovered deposits with the aggregated annual capacity 7 000 t;
- Development of joint ventures in Kazakhstan to the level 5 000 t per year.

ARMZ cooperates with domestic and foreign nuclear, energy, mining, industrial, financial and trading companies to attract investments in uranium mining.

Nuclear industry in China

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This presentation will discuss the role of nuclear energy in China. It will commence with a summary of the overall situation for electricity generation and the importance of nuclear energy, outlining the major electrical power entities, why nuclear power currently only provides 1.9% of the electricity generated in China, why nuclear power has a major future in China along with coal and hydro power, and the roles of the China National Nuclear Corporation.

It will then provide more information on the 11 operating NPPs, the 11 reactors under the construction in China, and the plans for the future.

The current plan for 2005-2020 is to reach 40 GWe for NP by 2020, but the Chinese government is modifying this plan to increase the nuclear power target to 70 GWe along with other 30 GWe under the construction. Is it dream or will be implemented in the future?

The total drilling footage finished in last two years reached 950 000 meters (450 000 meters in 2007 and 500 000 in 2008) including the 700 000 meters focused on the sedimentary basins in the northern China. The uranium resource and reserve in the northern China are dramatic increased. The new discovery resulted three large uranium deposits named Mengqiguer deposit located in the southern margin of Yili basin in Xinjiang, Sunjialiang deposit located in northern part of Erdos basin and Nuheting deposit of Erlain basin located in Inner Mongolia, two medium size deposits called Subeng deposit located in Erlain basin and Baixingtu deposit located in Songliao basin of Inner Mongolia respectively. And the potential areas such as Ciyaobo of Erdos basin, Shazhaoquan of Badanjilin basin in Inner Mongolia, Honghaigou of Yili basin are localized to make sure of future targets and prospects. Those prove that the future exploration focus will be given to the basins located in the northern China to discover more uranium resources. Meanwhile the progress to find more uranium resources in the southern China achieved and a large uranium deposit called Julongan deposit of Xiangshan uranium field in Jiangxi province and two medium size deposits named Heshang deposit of Xiangshan field and Xiangyangping deposit of Ziyuan field in Guangxi autonomous region were discovered.

Finally the presentation will examine uranium requirements and production. There are plans for production from 10 major uranium deposits, linked to 6 milling and processing centers in China. China is intensifying its exploration and development program; last year, it drilled more than 0.5 million meters in exploration for more uranium resources. Meanwhile, China is increasing its international activities, including the construction of new mines and mills abroad, and direct purchases from the international market. It will outline how the government is developing policies to help meet future requirements of uranium.

Technical developments in uranium mining and milling in India

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Uranium mining in India made a formal beginning with formation of Uranium Corporation of India Ltd. in October 1967. In accordance with the mandate of producing and meeting the uranium requirement of the country, UCIL has continuously upgraded the technology and operating practices with regard to its core activities - uranium ore mining, processing and disposal of tailings.

Jaduguda underground mine in Singhbhum east district of Jharkhand (Eastern India) was commissioned in 1968. Regular mining operations started with the sinking of a fully lined vertical shaft and equipping the same with two winders which support a cage and a skip. This was followed by commissioning of Bhatin mine in 1986, Narwapahar mine in 1995, Turamdih mine in 2003, and Bagjata mine in 2008. New mines adopt decline method of entry and use of track less equipment in cut-and fill method of stoping. Vertical shafts provide access to deeper levels for ore and men & material hoisting. Banduhurang, the first opencast uranium mine of the country was commissioned in Jan 2009. New mine at Tummalapalle in Andhra Pradesh and underground mine at Mohuldih in Jharkhand are under construction. The mine at Tummalapalle has been planned with three declines along the apparent dip of the orebody and breast stoping method using trackless equipment. At Lambapur-Peddagattu in Andhra Pradesh, room and pillar method of stoping is proposed for underground mines with deployment of low profile drilling and loading-dumping equipment.

The conventional way of processing of uranium ore in India is through hydro-metallurgical route followed by acid leaching and MDU precipitation. Jaduguda plant commissioned in 1968 has been expanded in two phases and 3rd phase expansion is underway. The plant at Turamdih encompasses new equipment and monitoring systems like apron feeder, horizontal belt filter, high rate thickener, particle size monitor etc. Both Jaduguda and Turamdih plants are designed to produce magnesium di-uranate (MDU) as the final product. Through in-house research, precipitation of uranium peroxide ($UO_4 \cdot H_2O$) as final product is under implementation. Since 2007, the plant at Tummalapalle is under construction which will adopt alkali leaching (under pressure) route.

The operating underground uranium mines of the country are carefully designed with suitable stoping method (cut-and-fill) to accommodate maximum tailings. The finer fraction of the neutralized tailings is disposed in engineered impoundment facility, called tailings pond. The first two tailings ponds at Jaduguda are full and are under reclamation. The third pond is in use now. The tailings pond at Turamdih has been designed with some improved floor lining to prevent any downward movement of effluent. The proposed opencast mine at KPM in Meghalaya is also being designed to sequentially store uranium tailings and backfill material. At Lambapur uranium project, thickened tailings disposal system has been proposed where small dykes shall be built to contain tailings.

The uranium ore mining and processing technology in India has come a long way in emulating global practices which has helped to develop the low grade deposits in cost effective and eco-friendly manner. This sector is now ready to acquire overseas uranium properties in order to expand the production base.

Social Licensing in Uranium Production Cycle

AREVA's social licensing experience in Northern Saskatchewan, Canada

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The Athabasca Basin area in the northern part of the Province of Saskatchewan has for many years been the world's leading uranium producing region. The current generation of projects date back to the 1970s, and in addition to a strong record for safety and environmental protection, have featured a complementary focus on social considerations.

AREVA Resources Canada Inc. is the majority owner and operator of two of these projects. The Cluff Lake Project operated from 1981 to 2002, and is well advanced with decommissioning. McClean Lake Operation commenced operation in 1999 and has a lengthy future. This paper will discuss the development of these projects from the perspective of obtaining and maintaining a "social licence". It will briefly describe the physical and socioeconomic environment, and the main public policy decisions underlying the approach to social licensing. It will then describe the various socioeconomic programs, including the challenges and successes in their implementation. It will conclude with a brief look at future challenges and opportunities. The socioeconomic programs are supported by our joint venture partners, and AREVA Resources Canada supports similar programs in projects where we have a minority joint venture interest.

Overall, the experience of AREVA Resources Canada in northern Saskatchewan reflects the AREVA Group's approach to sustainable development, tailored to the specific local environment of our projects.

Social licensing in the uranium cycle production (case of Niger)

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In Niger Republic, uranium exploitation has begun since 1970. It is an economic resource but also causes social and environmental problems. To exploit according to the rule, to protect social environment, to work in safe conditions and contribute to the development of local population one side and Niger Republic in the other side, a mining law was voted in March 1993. It is about the ordinance n°93-16 on mining law which was modified in August 2006 by a new mining law, the ordinance n°2006-26 of August 09, 2006. As well as the presidential decree affecting the application of this new law was issued. Other legislative and regulatory texts have been taken as far as exploration and exploitation mining. For example, the mining agreement, the order n°0073/PM of July, the 4th, 2005 relative to the transparency on mining exploitation; ordinance n°97-001 of January the 10th, 1997 appointing the environmental studying impact and the law 98-56 of December the 29th, 1998 relative to the management of environment.

For acquisition of an exploration licence or a mining licence, a mining agreement is signed between the mining company and Niger Republic which makes clear social, environmental, financial, economic...conditions in which the mining company must exploit natural resources. The ordinance n°93-16 of 2 March, 1993 related to the mining law in chapter IV, clarifies conditions for acquisition of exploration and mining licence in Niger Republic. It clarifies again in the same chapter, title VI, rights and obligations relating to mine or quarry operations for companies and tax provisions relative those activities. In the same order, in title VIII, hygiene and security conditions in mines are been specified. The mining agreement in title IV, specify rights, obligations and administration in mining activities, particularly article 18.2 which stipulates "the mining company undertakes to contribute to the development of municipalities in which it shall carry out activities, by contributing to the funding of collective infrastructure".

The government must look after the application of this mining convention. This new mining law and the others legislative texts provide for in some articles the social obligations of the mining company in which the exploitation must be done for the local population in the way of lasting development.

In this presentation, all articles of the mining law and other legislative, regulatory that treat the Social Responsibilities Companies (SRC), the social obligations of the company will be more detailed.

Uranium mining and stakeholder engagement in the Northern Territory, Australia

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Uranium has been mined in the Northern Territory of Australia more or less continuously since 1949. Most of these mines have been located on Aboriginal land, although in many cases Native Title has only been recently established and the rights of the Traditional Owners finally acknowledged. In earlier days consultation with the Traditional Owners was generally unheard of and few sites were rehabilitated when mining ceased. However, leading practice in modern mining, including uranium mining, requires that these two issues are paid particular attention, whether it be for development and operation of current mines or the remediation of legacy sites.

The paper presents two brief case studies in relation to stakeholder engagement developed in the Alligator Rivers Region uranium field of Australia's Northern Territory. The subject of the first case study, the South Alligator valley, was subject to intensive prospecting and exploration which resulted in the development of 13 small uranium mines between 1955 and 1964. The operations were abandoned and the area returned to being a cattle ranch. In 1987 the valley lay within an area that was incorporated into the World Heritage-listed Kakadu National Park. In 1996 the Gunlom Land Trust was granted native title to the area under the Commonwealth's *Northern Territory Land Rights Act (1976)*. The new owners immediately leased the land back to the Commonwealth Government for continued use as a National Park. A condition of that lease was that all former mine sites and associated workings would be rehabilitated by 2015. The paper describes the comprehensive consultation process involving all stakeholders that was developed for this programme; and goes on to describe the programme of remediation works to date and the situation as of 2009.

The second case history deals with the consultation process developed by one Government agency as it works with Traditional Owners and other stakeholders in maintaining surveillance over the operating Ranger Uranium Mine. The Supervising Scientist Division of the Commonwealth Department of the Environment, Water, Heritage and the Arts is responsible for environmental oversight of the mining operations and has developed a number of systems for engaging stakeholders which have stood the test of time. These are described in the paper which ends with a brief overview of recent publications on this topic from IAEA, the uranium industry and others.

Environmental protection in the management of closed uranium mining sites in France: a pluralistic expertise approach for assessing short, medium and long term options

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Evolving public concern and regulations call for a growing stakeholder involvement in the protection of the public and the environment. When it comes to technically complex issues prone to diverging perceptions of risks, decision making processes can be usefully advised by the pluralistic examination of the issues by a group of institutional and non-institutional experts. Raising controversies over the remediation status of French closed uranium mining sites lead the French ministers for the environment, health, and industry to create such a pluralistic expert group (GEP) in the end of 2005, with a focus on central Limousin region. This group brings together more than 40 experts with various skills and backgrounds from public institutions, industry, local and national environmental organisations, as well as independent and foreign experts. The group is committed to three main tasks to:

- (a) contribute the critical analysis of the status of the sites, based on extensive technical assessments provided by the operator AREVA NC (formerly COGEMA) and by the French Institute for Radiological Protection and Nuclear Safety (IRSN);
- (b) provide the authorities and the operator with recommendations on long-term management and monitoring options for the facilities, with the aim of reducing the health and environmental impacts;
- (c) report to local stakeholders and to inform the general public.

Work has been developed in three complementary areas:

- improving the assessment of releases to the natural environment,
- developing a more thorough assessment of health and environmental impacts; and
- strengthening the principles of management and monitoring of the potential impacts on the longer term, in the light of the applying regulatory framework and the conventional wisdom on long term scenarios.

The GEP, which is due to conclude its work in the end of 2009, therefore aims at demonstrating the usefulness of pluralistic expertise to develop a more comprehensive assessment of technical issues usually dealt with, and to extend the scope of analysis to more society oriented concerns, therefore providing better guidance to decision making for the minimization of long term impacts on the public and the environment.

Social license and environmental protection: When compliance with regulations is not enough

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The Social License to run a business became a real need to the industries that can cause significant environmental impacts. Experience shows that independently of the size of a particular mining operation several projects have been stopped or delayed due to strong opposition of local communities and Non-Governmental Organizations (NGO's) Traditionally, corporations see compliance with the legal requirements as a synonym of observance of social obligations. However, it has been recognized that without the so called "Social License" businesses can be seriously affected, even if the operation holds the necessary legal licenses (environmental, nuclear, etc). Despite corporations and regulators seem to fully accept the need of a social license, there is a need to establish mechanisms that can allow for the full and effective implementation of Social License. In Brazil, Indústrias Nucleares do Brasil (INB), a state owned company, is in charge of the production centre of Caetite located in the state of Bahia. This is the only production centre in operation in the country. The ore grade is about 0.29% and is mined by open pit operations. The plant started operations in 2000 and the extraction process is Heap-Leach. The region presents a semi-arid climate and because of that the local community heavily depends on the supply of groundwater, also of key importance for the operations of the milling plant. Safety assessments demonstrated that groundwater is the potentially most affected medium regarding the mining and milling operations. However, in the area of influence of the plant the potential of groundwater contamination is very restricted as a consequence of the existing geological features of the rocks. The high uranium concentrations observed in one of the neighbor communities - Juazeiro - located in an uraniumiferous province are linked to geochemical process of uranium dissolution from the rocks and cannot be attributed to the mining and milling operations. However, the perception of the population is that the higher concentrations are due to the industrial activities. Recently the situation deteriorated even more as a NGO with international activities, produced a report in which the elevated natural concentrations of uranium, in groundwater used by the community of Juazeiro, were correlated with the operation of the uranium plant. As a result of this document the local products were severely affected in terms of their acceptance by neighbor communities causing heavy socio-economical impacts. It is also very common that any operational incident taking place at the mining site is immediately perceived by the population as a threat to their well-being. In addition to the distrust on the operator, there is also fear that the controls exerted by the Regulatory Authority do not warrant the necessary level of safety to the population. . During the licensing process stakeholder involvement took place mainly by means of public hearings. Even after these hearings many more meetings took place, but these events were not enough to improve the overall situation. As a result, different mechanisms to bring more confidence to the population on the safety of the operations have been thought about. They include, among other initiatives, the implementation of Environmental Management Systems; support to be given by the operator to the establishment and development of sustainable economical activities aimed at improving the life-standards of the local population and international peer review missions (leaded by international organizations like the IAEA) to bring independent scrutiny to the operations. These initiatives will be presented and discussed during the conference. The paper will also address some other mechanisms that mining companies can pursue to demonstrate their commitment with local communities.

Uranium Exploration
&
Geology

Uranium exploration, resources and production in South Africa

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The international uranium industry experienced a nuclear winter for almost two decades from the early 1980s to the early 2000s. The uranium price fell from over US\$40/lb U₃O₈ in 1979 to below US\$10/lb U₃O₈ where it remained for well over a decade. This had a dramatic effect on the uranium industry in South Africa. South Africa commenced uranium production in 1952 and was one of the top three uranium producers of the Western World for decades. In addition it was ranked in the top three with regard to uranium resources. Peak production of just over 6 000 tU was achieved in 1980 when South Africa produced 14% of the world's reported production. A total of 15 mines were actively producing uranium as a by-product.

South African production steadily declined from 1984 onwards as more and more mines closed down their uranium extraction plants. Production fell below 1 000 tU for the first time in 1998 when only four mines were producing uranium. The decline continued until 2007 when only one mine produced less than 10% of South Africa's peak uranium production. South Africa only ranked 11th in the world's uranium producers in 2007. However it was still ranked 4th in the world in terms of recoverable resources in 2007. The nuclear renaissance that the world has been experiencing in recent years saw the uranium price climb above US\$10/lb U₃O₈ in 2003 for the first time in almost two decades. The rocketing price in 2005 to 2007 stimulated intensive exploration activities in South Africa.

A number of Witwatersrand gold mines re-evaluated their resources both in their underground operations and surface tailings dams. Uranium production was discontinued at most mines but ore was still mined for its gold content and the resultant uraniferous tailings dams constitute easily accessible resources which are also relatively cheap and easy to exploit. The Karoo sandstone deposits received considerable attention and are still being intensively investigated as are the coal hosted deposits of the Springbok Flats north of Pretoria. The decline in the uranium price has dampened the level of exploration activities but they are continuing albeit at reduced levels.

A number of companies announced production plans and are actively working towards increasing or commencing uranium production. Unfortunately the decline in the uranium price has caused one operational mine to cease production and be placed on care and maintenance. Others are continuing with development but in some instances the pace of development has been slowed down and is being reassessed. If all the announced planned uranium production capacity is brought on line then production could exceed 5 000 t U₃O₈ per annum. This would be well in excess of the requirements for the envisaged South African nuclear expansion plans. Future production is likely to be contracted out on the international market with Eskom just being one of the customers. The government has released a nuclear energy policy document for South Africa in which it states that the nation's uranium resources will be used in a sustainable manner and that uranium beneficiation would be encouraged.

South Australian Uranium Mineral Systems: A spectrum of mineralization across the ages and across styles (“uranium is where you find it”)

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South Australia hosts two of Australia’s three Uranium mines, with another due to begin production within a year. Most importantly, the State’s uranium deposits and prospects display a broad range of genetically and spatially related mineralisation styles and ages. Crystalline basement is intruded by 1 600-1 580 Ma Uranium-rich granitoids that are the probable source to a wide variety of potential geological host rocks within the broader Uranium mineral system, via remobilisation into older and younger rocks (hydrothermally, structurally and within basins and channels).

Currently four host types (and variations between them) are explored for: Breccia complex deposits are formed at high crustal levels in active hydrothermal and/or phreatomagmatic systems and occur in a range of host rocks, but Uranium enrichment is proportional to proximity of Mesoproterozoic granitoids. Examples of this type of “IOCG+/-U” deposit include the Olympic Dam deposit. Olympic Dam is within a iron-rich belt hosting Prominent Hill, Carrapateena, Acropolis, Wirrda Well, Canegrass, Oak Dam and Punt Hill. Mount Painter uranium occurrences are hosted by the Palaeozoic Radium Ridge Breccias within Proterozoic basement, including the Armchair, Streitberg, Radium Ridge and Mt Gee prospects.

Roll-front deposits are hosted by medium to coarse-grained fluvial, marginal marine or alluvial sands draining off uraniferous basement rocks. Spatial association with basement faults and non-channel sands adjacent to basement highs are noted (e.g. Beverley 4 Mile). South Australia contains significant examples of Tertiary roll-front deposits, including Beverley and Honeymoon within the Callabonna Sub-basin, and Warrior and Yarranna prospects of the Eucla Basin. The Beverley Deposit is the only deposit of its type currently being mined in Australia, although Honeymoon is due to begin production in the near future. Mineralisation across various deposits can be in different stratigraphic horizons as well as different morphologies. Some examples may impinge upon basement rocks and unexpectedly show some controls related to unconformities.

Vein style deposits are hosted by cavity fill (fractures, veins, apophyses) and can be related to fault planes and shear zones. In some cases, these may be variably remobilised examples of other styles and are transitional examples. The most significant area for this style of deposit in South Australia has historically been at Radium Hill and Crocker Well within the Curnamona Province.

South Australia hosts more than a third of the world’s known uranium resources, and while these are largely contained within Olympic Dam, this and the other examples reveal a unique and complex interplay of mineralising mechanisms. Globally, in areas where there are already higher than average uranium contents in a regional sense there is likely to be more than one style of uranium mineralisation reflecting both spatial and temporal variations in geological conditions, largely related to redox reactions.

An overview of uranium exploration strategy in India

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Uranium exploration in India dates back from 1949 and the first mineralized area was located in the early 1950s in Singhbhum Shear Zone (SSZ), eastern India. Since then, a number of potential and promising uranium provinces have been established in India. The potential uranium provinces include SSZ, Dongargarh, Umra, Siwalik belt, Mahadek basin, south-western and Northern parts of Cuddapah basin, North Delhi Fold Belt, Bhima and Kaladgi basins. The promising uranium provinces are Proterozoic Chhattisgarh, Indravati, Gwalior, Vindhyan, Shillong basins, Gondwana basins of Central India and semi-arid regions of western Rajasthan.

With the establishment of large tonnage-high grade Lower-Middle Proterozoic unconformity deposits in Canada and Australia, there was a paradigm shift in the exploration strategy towards the Proterozoic basins of India. The discovery of unconformity related uranium mineralisation in the northern part of Proterozoic Cuddapah basin in southern India in 1991 and establishment of few deposits in the province has opened the avenues for finding of similar deposits in Cuddapah and other 13 Proterozoic basins in India. As a sequel, Proterozoic Bhima basin in southern India has been recognized as a potential target for uranium mineralization, where a low tonnage-medium grade deposit has been established and mine development works are in progress. Sustained exploration efforts in other Proterozoic basins have yielded success in a few basins such as Deshnur area in Kaladgi Basin of southern India. Considerable uranium resources have been established in Proterozoic Cuddapah and Bhima basins.

Apart from northern parts of Cuddapah and Bhima basins, areas in the southwestern part of Cuddapah basin for stratabound type, where a mine is under construction; Proterozoic Kaladgi basin for vein type; Cretaceous Mahadek basin for sandstone type and the North Delhi Fold belt for vein type of mineralization have been prioritized as potential areas for exploration. Airborne and ground geophysical techniques with adequate support of exploratory and evaluation drilling are expected to produce quicker results.

The second priority is in the promising areas, where substantial ground radiometric and geochemical surveys have indicated the presence of uranium in the system. These comprise Proterozoic basins such as Chhattisgarh, Vindhyan, Gwalior, Bijawar, Indravati and Shillong basins for unconformity type; Gondwana sediments of central India for sandstone type; Central and Eastern Indian craton for iron oxide type; QPC type in parts of central and eastern India and surficial type of uranium mineralization in the semi-arid regions of western Rajasthan.

Uranium exploration in India is now geared up to face the challenges of fuel requirements for the rapidly growing domestic nuclear power industry. Exploration activities both in potential and promising uranium provinces have been planned for the next ten years. Comprehensive exploration strategy for every province is being executed to address specific exploration targets.

The exploration of the uranium in the Hoggar, Central Sahara, Algeria: Typology of uranium occurrences discovered and prospects of revival

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The first research works of uranium in the Hoggar (1953 – 1958), focused around younger granites (granites of Taourirt) and Pan-African granite, have highlighted the first Timgaouine - Abankor and Aït Oklan - El Bema uranium clues, an intrabatholithic vein ores, all circumscribed in the eastern pharusian chain branch (western Hoggar). A second detailed investigation (1969 – 1974) allowed the development of the known uranium clues into uranium deposits of Timgaouine – Abankor. The enlargement of such works to the cover of sedimentary basins at the Hoggar border led to the discovery of the Tahaggart uranium deposit and the Timouzeline and Tamart-N-Iblis uranium clues, uranium occurrences enclosed at the basement-cover interface and palaeozoic continental sandstone horizons of the Tin Séririne sedimentary basin (South-East of Hoggar). In the prospect of an uranium exploration revival in the Hoggar, the adopted approach is illustrated by the example of the uranium ores highlighted in Tin Séririne basin. This southern region of Hoggar, with its extension in the basin of Tim Mersoï in Niger, is compared in regional metallogeny to the cross-border uranium province (Algeria, Niger). It is characterized by a set of uranium occurrences, which fit at different levels of the sedimentary series, on both sides of the In Azaoua fault-flexure. These are mainly represented by: Tahaggart (Cambro-Ordovician), Tamart-N-Iblis– Timouzeline (lower Devonian), Arlit – Alette – Akouta – Madaouela (higher Carboniferous), Imouraren (Jurassic) and Takardait – Azélik (Cretaceous). They illustrate the example of a metallogenic permanence which spread out from the Cambro-Ordovician to Cretaceous (420 m.y). The application of updated methods and technique (sequential stratigraphy, interpretation of airborne geophysics data, ...) to the exploration of this southern margin of Hoggar targets a better knowledge of the uranium metallogenic processes (source – carrying – deposits) at different levels of the paleozoic series to guide the future exploration programs.

Uranium exploration in Paipa and Iza area (Colombia), new contributions (Preliminary report)

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This paper shows the preliminary results from uranium exploration of the Boyaca Department, for the first survey conducted by the Colombian state after 26 years. The exploration is carried out this year and the zone covers an area of 460 square kilometers divided into three sectors, determinate from an analysis and appreciation of literature and field; these sectors are located in the municipalities of Sogamoso Paipa, Iza, Tota and Pesca, Chivata and Tuta.

In the area is dominated by sedimentary rock since the Cretaceous age to tertiary and sediments of the Quaternary. In Paipa, and Isa outcrops volcanic and sedimentary rocks; the major structural features are Arcabuco anticline, Los Medios syncline and Boyaca and Soapaga faults. The sedimentary formations from the oldest to most recent in the area are: Tibasosa Formation; Une Formation, Conejo Formation; Plaeners Formation; Los Pinos Formation; Labor y Tierna Formation, Guaduas Formation Socha Formation; Picacho Formation an Concentration Formation; in the area outcrops also, volcanic rocks (riolites porphyrites and andesites); and explosive (pumices).

In the Paipa Area, was found three anomalous sites (Durazno, Quebrada Honda and Casa Blanca) with values ranging between 440 and 7 500 aps the highest values was reported in the Durazno area. The outcrops are found in volcanic rocks (tophus) and tectonic breccias in the presence of thin strips of coal from the Guaduas Formation present there. In the year 1979 in studies by ENUSA (Spain) the highest values were reported from 3 800 aps. In Iza, was found five anomalous zones (El Crucero, San Miguel, Cuitiva - Iza, Erika and Tota - Pesca) with values ranging between 480 and 4 480 aps; outcrops in igneous rocks in Erika sector; and the highest values in phosphates was found in El Crucero sector with a maximum value of 2 100 aps. In holes made in Iza the values fell from 1 200 aps in surface to 4 480 aps in depth (1.60 m). In Paipa, we have values from 4 500 in surface to 7 500 aps at 1.50 meters, so that next year (2009), we will have some drills in Paipa as Iza in order to learn more about their behavior in depth and geometry of the potential deposits.

Potential and existing uranium resources of the Middle East and North Africa

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This study integrated evidences from structural frameworks, geologic environments and geochemical-metallogenic indicators for uranium deposits to predict some uranium-bearing provinces in the studied countries (Egypt, Iran, Iraq, Jordan, Saudi Arabia, Sudan, Syria, Turkey, UAE, Oman, Qatar, Kuwait and Yemen, Algeria, Libya, Morocco and Tunisia).

The study found that the Pan-African granites are one of the most suitable environments to host vein-type uranium deposits. The uranium mineralizations are hosted in these granites within some favorable structures such as faults and fractures. The uranium minerals are mainly secondary (primarily uranophane) and occasionally some pitchblende and uraninites are present. They are associated with sulphide as pyrite, chalcopyrite, galena, sphalerite and molybdenite. The gangue minerals are mainly iron, manganese oxides and fluorite. The most associated alteration features with this gangue are hematitization, silicification with black silica veins, carbonatization and the presence of fluorite. Volcanic rocks represented another potential source for uranium in many of the studied countries. The volcanics range in age from 74 to 302 MY and some of them host uranium or uranium/thorium mineralization.

The presence of intra-cratonic basins is also observed within many basement rock exposures in the study area. Often these basins are filled with late-Proterozoic molasses-type sediments such as the Hammamat series in Egypt, and can form important uranium traps according to their geochemical and geological characteristics. This feature is well known in many of the studied countries especially in Algeria, Egypt and Saudi Arabia. The present study also documented evidence of the presence of intra-cratonic basins filled with Paleozoic sequences; the lower horizons of these sequences have potential for hosting uranium resources. This was noted in Libya (Morzok basin) and in Egypt (Wadi El Kharite basin). The Unconformity uranium deposits could exist in some countries such as Algeria and Egypt. Good potential was found in Paleozoic rock sequences in many of the studied countries. In addition, surfacial uranium deposits were reported in Jordan nearby some uranium-bearing phosphate deposits. Phosphorite belts in North Africa and the Middle East can form additional non-conventional uranium resources in several geographic regions. Black shales nearby the phosphorites can contribute to the uranium resources in many of these countries if studied thoroughly. Other potentials and related evidence for uranium deposits in the MENA region are also summarized in this work with detailed maps, data, coordinates, and analyses.

Levelling airborne and ground gamma-ray spectrometric data to assist uranium exploration

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Geophysical methods can be used for mapping in both two and three dimensions, as well as the direct detection of ore bodies. The gamma-ray spectrometric method is an efficient method for the regional assessment of uranium potential and the detection of surface mineralization. However, the full potential of the method can only be realised when the data are adequately standardised. In this paper, we present examples of this standardisation at both regional and local scales. At a regional scale, we show how the levelling of airborne gamma-ray spectrometry data over Australia increases the value of the resulting data, and on a local scale, we demonstrate a geometrical correction for ground gamma-ray spectrometry in shallow holes that improves the accuracy of measurements.

Most of Australia has been systematically surveyed using the gamma-ray spectrometric method over the past 40 years. However, many of the surveys were either inadequately calibrated, or the results were not reported in units of concentrations of K, U and Th. This limits the usefulness of these data, as it is difficult to compare anomalies detected on separate surveys, or to combine surveys into larger compilations in order to interpret regional features in the data. To solve these problems, Geoscience Australia flew an airborne gamma-ray spectrometric survey over the entire Australian continent with a 75 km line spacing to serve as a radioelement baseline for all current and future airborne gamma-ray spectrometric surveys in Australia. The survey was first back-calibrated to the International Atomic Energy Agency's (IAEA) radioelement datum, and then used to bring all the public-domain airborne gamma-ray spectrometric surveys in Australia to this datum. Interpreters can now use the levelled data to reliably compare the radiometric signatures observed over different parts of Australia and to interpret large-scale regional features in the data.

Ground gamma ray spectrometry surveying with portable gamma ray spectrometers are carried out using specific source-detector geometries. Examples include a flat earth ($\omega = 2\pi$ sr), in shallow holes ($\omega > 2\pi$ sr), or at low altitudes above the surface of the earth. The latter is often the case with dynamic measurements. Since portable gamma ray spectrometers are calibrated for an infinite half-space source-detector geometry ($\omega = 2\pi$ sr), K, U, and Th radioelement estimates derived from portable spectrometer measurements with other source-detector geometries will be either positively or negatively biased. A field investigation of the K, U and Th response of a portable multichannel gamma ray spectrometer to measurement in shallow hole to a depth up to 0.4 m, and to the measurement above the Earth's surface up to the height of 3 m was conducted in an area of crystalline rocks of medium radioactivity in the Czech Republic in 2008. Estimates of the geometry corrections enable the compilation of radioelement maps and the comparison of anomalies from ground measurements taken under a variety of source-detector geometries.

The application of borehole seismic techniques in mine development at the millennium uranium deposit, Northern Saskatchewan, Canada

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The Millennium uranium deposit (indicated resource of 469 500 t at 4.53% U₃O₈) is located within the Athabasca basin of northern Saskatchewan, Canada. The deposit is hosted within steeply dipping Lower Proterozoic basement rocks, unconformably overlain by 500 m to 625 m of flat lying Athabasca Group sandstones. The deposit is associated with multiple graphitic faults, some of which are associated with post-Athabasca movement that has contributed to over 100 m of unconformity offset proximal to the deposit. The mineralization process has also resulted in intense hydrothermal alteration of the host rocks, and to a lesser extent the sandstone units located above the mineralization. All of these factors complicate the hydrological setting around the deposit, a factor that has to be accounted for in mine development.

The pre-feasibility study for mine development commenced in 2007. In an attempt to minimize costs related to shaft sinking the proposed mine development was located to the east of the deposit, hanging wall to the mineralization. Two shaft pilot holes (CX-62 and CX-63) and an inclined exploration drill hole (CX-61) were completed in this area early in 2007. Single hole (Side-scan) seismic surveys were then completed in the shaft pilot holes and a multi-offset VSP (Vertical Seismic Profiling) survey in drill hole CX-61 in an attempt to: 1) map vertical to sub-vertical structure in the vicinity of the proposed mine shafts; 2) map unconformity offsets located in proximity of the proposed mine infrastructure and; 3) add to the geotechnical knowledge of the sandstone within the study area. The surveys successfully imaged subvertical structures and unconformity offset, adding insight into the hydrological controls within the study area. These surveys are now accepted by Cameco Corporation as a prerequisite for shaft sinking given the cost implications related to recent water inflow at minesites located within the Athabasca basin.

Applied electromagnetic methods in the search for shallow unconformity related uranium mineralisation in Australia

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Airborne and ground electromagnetic surveys have been used over many years to explore for unconformity related uranium mineralisation in Australia. The application of electromagnetic techniques in the Australian environment is regarded as a specialist approach due to poor conductivity contrasts often observed between sedimentary cover sequences and basement rocks. Strong basement conductors are rarely seen in prospective geological terranes and it is often a requirement of the electromagnetic survey to resolve thin, weakly conductive horizons in highly resistive surroundings.

Logistical and physical constraints play an important role in determining the type of survey applied, and to some extent, the success of the survey.

Examples of airborne and ground electromagnetic surveys from prospective terranes in the East Kimberley, Ashburton and West Arnhem Land regions of Australia demonstrate the applicability to exploration with results highlighting both successes and failures. Survey data demonstrate the electromagnetic induction effect in relation to host rock alteration proximal to the unconformity.

An airborne electromagnetic survey flown in the Ashburton region of Western Australia shows how the search for unconformity related mineralisation has lead to completely unexpected results.

Geophysical testing of low-grade uranium ore technogenic formations

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Monitoring of tailing pits of uranium ore conversion products and reserve supplies of low-grade ores stored in dumps is traditionally based on radiation environment on these sites and adjacent territories. The results of gamma-ray spectrometry of solid fractions and radon concentration measurement in liquid and gas phases of technogenic formations are used in radiation hazard evaluation.

The monitored sites are known to contain associated elements besides uranium and decay daughter products. Ionic forms of some of them define the migration activity of radioactive nuclides, others possess toxic properties (arsenic, lead, antimony, mercury, selenium, molybdenum, etc.).

For instance, the increased content of calcium carbonate and sulphuric acid in natural water solutions promotes active uranium migration whereas ferric iron presence causes high effectiveness of uranium leaching in rocks (dissolution of uranium-containing minerals). Radium tends towards migration in highly saline chloride-bearing solutions.

Radiometric testing practice of low-activity field formations in loose and lump masses shows that due to high emanating ability it is necessary to use dual-channel radiometer for ionizing radiation background record and compensation. Thus gamma-radiometry is not the direct method of uranium content determination and alfa- and beta-radiometry can be correctly used only for sample analysis in laboratory environment.

Consequently, distant express testing with the help of X-ray radiometric (XRM) instruments (on calcium, iron, manganese, titanium, copper, arsenic, lead, strontium, selenium, molybdenum, uranium, etc.) is recommended for additional introduction in field observations of radio-ecological environment in mining and processing production tailing and dumps of low-grade ore reserve supplies. Thanks to preliminary areal schemes of geochemical zonality as per XRM data XRM application allows to use the sample limit, given for a wide range of laboratory analyses rationally. Sampling places and their number as well as kinds of laboratory analyses are chosen based on XRM data.

It is rather effective to use laboratory variant of atomic absorptive analysis on mercury and stibium in gases (GA), generated in the process of grated samples calcination in muffle furnaces.

During the presentation of the report In order to prove the effectiveness of XRM and GA presentation graphics with the results of areal mapping using the above methods and geochemical testing on the territories of Tashkent (Uzbekistan) and Chimkent (Kazakhstan) regions within the framework of the geological and ecological mapping project on the above specified territories.

Proposed metallogenic and tectonic classification of uranium ore deposits types

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The behavior of uranium in the natural environment is very versatile. It has a crustal abundance of only 4 ppm, about the same as tin or arsenic, however it is found concentrated into uranium deposits in many different types of rock and geologic environments, in concentrations of 20%, or more. Uranium has two different oxidation states in nature. The plus four (+4) oxidation state is present in reduced conditions, meaning all magmas. In the more oxygenated surface and near-surface regions the plus six (+6) oxidation state is present in the form of the uranyl molecule or ligend, O-U-O ‘dumbbell’ shaped molecule, (UO₂)²⁺. This cationic molecule hydrologizes, is very soluble in water, and is transported in this manner. This is partly the reason for the versatility of uranium. The precipitation of uranium from surface or groundwater is necessary for the formation of several types of deposits. First, chemical reduction is a most efficient method of precipitation, reductants being carbon or sulfur in the forms methane (natural gas), hydrogen sulfide, coal, organic materials, or shale. Independent of oxidation/reduction, the uranyl cationic molecule in water has attraction to a large variety of anionic liginds, including those of As, P, V, Mo, and where the concentrations are large enough, the solubility product is exceeded, and precipitation takes place. The fact that uranium mineralogy consists of over 100 different species which are members of many anionic mineral families attests to the versatility of uranium. As a result of these properties of uranium, there are many different uranium deposit types and subtypes, and many different deposit type classifications. Since countries have different geologic characteristics, classifications tended to reflect national characteristics. The IAEA in 1988 provided its classification based on uranium production by type, and this is of widespread use. Significant problems exist in understanding genetic relationships between certain uranium deposit types, and the magmatic hosted deposits are most problematic. Several deposit types are the name of a known deposit, such as Rossing, Namibia type, or the Bokan Mountain, Alaska, type, with no relationship between them. It is an objective of the present report to provide an integration and synthesis of the various magmatic uranium deposits. A model is presented integrating the following deposit types 1) metasomatic, 2) magmatic, 3) pegmatitic, 4) contact metamorphic, 5) hydrothermal veins., and 6) carbonatite, within a regional tectonic understanding., Another significant problem is demonstrated by a group of the surficial deposits. The origin of uraniferous coal, lignite, phosphate, and black shales are unified with the recent suggestion that the uranium comes from giant caldera ash eruptions from silicic large igneous provinces (SLIP) in adjacent extensional regimes. This implies that all four surficial regimes can be mineralized by the same event. This realization can be a significant global exploration tool. The proposed classification provides a better understanding of the origin of uranium deposits, and consequently can lead to a more effective exploration program.

Uranium in Mongolia

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Mongolian electricity is produced from fossil fuels (about 98%, mainly coal). Rapid growth in demand has given rise to power shortages, and the reliance on fossil fuels has led to much air pollution. Mongolia does not have nuclear reactor and thus is not a beneficiary of nuclear technology. In April 2008 Russia and Mongolia signed a high-level agreement to cooperate in identifying and developing Mongolia's uranium resources. Russia is also examining the feasibility of building nuclear power plants in Mongolia. In our government need to create the environment for investment in nuclear power, including professional regulatory regime, policies on nuclear waste management and decommissioning, and involvement with international non-proliferation and insurance arrangements. Some 46 million kilowatt-hours of electricity are produced from one tones of natural uranium. The production of this amount of electrical power from fossil fuels would require the burning of over 20 000 tonnes of black coal or 8.5 million cubic meters of gas. Mongolia has a long history of uranium exploration commencing with joint Russian and Mongolian endeavors to 1957. Today the Canada-based Khan Resources owns a 69% share in the Dornod project through its subsidiary Central Asian Uranium Co. Ltd and Russia's Priargunsky Mining & Chemical Enterprise owns a further share. In 2007 Khan published NI 43-101 compliant indicated resource figure of 25 000 tU for the project, including probable reserves of 7 000 tU. A bankable feasibility study is now being undertaken, with capital cost estimate being US\$283 million and first production in 2011. Khan has applied for a mining licence from the Mineral Resources and Petroleum Authority of Mongolia (MRPAM).

The geology of the Kayelekera uranium mine

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The Kayelekera Uranium Deposit is located in the Northern part of Malawi, Southern Africa, 40 kilometres west of the township of Karonga. Paladin Energy Limited, an Australian based company holds an 85% interest in the Kayelekera Project through its wholly owned subsidiary Paladin (Africa) Limited. The other 15% is held by the Republic of Malawi.

Kayelekera is a sandstone hosted uranium deposit of the rollfront type. At a 300 ppm cutoff the deposit contains a total resource of 19 500 t of U_3O_8 with an average grade of 800 ppm. Reserves include 13 500 tonnes at 1 100 ppm.

The deposit is hosted by sediments of the Permian Karoo Formation in the North Rukuru Basin. Karoo strata within the North Rukuru Basin contain several hundred meters of sediments including Basal Beds, Coal Measures, and North Rukuru Sandstone. Uranium mineralisation is hosted by the North Rukuru Sandstone and occurs in four principal lenses developed within arkose units called S and T, the combined mudstone arkose Units U+V+W and arkose unit X.

Mineralisation is associated with redox fronts, resulting from oxidizing uranium-bearing fluids invading a reduced sandstone environment. The ore lenses are superimposed vertically along the axis of a shallow northwest trending syncline. A subparallel fault structure cuts the eastern limb of the mineralised syncline. Uranium mineralisation occurs within reduced and oxidized arkose and is redistributed into mudstones along faults. Coffinite has been identified as the main primary uranium bearing mineral with uranite being present to a lesser degree. Secondary uranium minerals meta-autunite, boltwoodite and minor uranophane occurs in weathered, oxidized rocks near surface and along faults.

Paladin completed a Bankable Feasibility Study for the Kayelekera Uranium Project including a comprehensive EIA in early 2007 and was granted a Mining Lease in April of that year. Construction started in late 2007 and was completed in March 2009. Ramp up to nameplate production of 3.3 million lbs U_3O_8 from 1.5 million tonnes of ore is currently in progress.

Exploration for uranium in Argentina: New policies of reactivation

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The policy established by the National Government of Argentina in August 2006 related to resuming the Nuclear activity in the country, lead the CNEA through the Exploration of Raw Materials Manager (ERMM) to establish working strategies for the next 10 years. These strategies together with the assignment of an adequate budget will contribute to define new uranium resources, which together with the already known ones, will be used to supply the requirements of Nuclear Power and Research Plants in the future. Thus, the ERMM is applying a policy of human resources hiring new personnel in order to count with the minimum necessary workforce to reach these tasks. In Argentina known U resources are related to sedimentary, igneous and metamorphic environments. Considering the geology of the different regions, Argentina has been divided into 57 units in which the geological, geochemical, mineralogical and structural information is evaluated in order to estimate the uranium geological favorability of each unit. The final pursuit of this regional study is to circumscribe new areas with anomalous uranium contents in which prospecting and exploration should be carried out. These studies together with prospecting and exploration works are performed in the country by four exploration centers based in Salta (RN), Cordoba (R.Ce), Mendoza (R.Cu) and Trelew (RP). The works planned for each exploration center includes:

Regional Noroeste, Mina Franca Deposit: peri-granitic vein- type mineralization: 25% of surface exploration has been performed. Mineralized areas: Istataco and San Buenaventura correspond to an igneous-metamorphic environment, Sierra de Vaquería to a sedimentary one: Prospection stage.

Regional Centro, Mineralized areas: El Gallo: drilling stage and Donato: prospection stage, correspond to an igneous-metamorphic environment with intra and peri-granitic anomalies. Noya: prospection stage, sedimentary environment.

Regional Cuyo, Mineralized area: Western Sierra Pintada: prospection stage, volcano-sedimentary environment. Neuquina Basin area: prospection stage. Uranium anomalies hosted by sedimentary deposits. This area is being tested for the application of in-situ leaching techniques (LIS).

Regional Patagonia, East Pichiñán uranium District: it includes the Cerro Solo, El Ganso, Puesto Alvear, El Molino and Arroyo Perdido deposits hosted by sedimentary rocks. Exploration drilling and reserve evaluation are currently being developed in Cerro Solo, whereas exploration drilling is carried out in the other deposits. Laguna Colorada deposit: Corresponds to a volcano-sedimentary environment: an exploration-drilling program has been planned for this area. Mineralized areas Mirasol Norte, El Cruce, El Picahueso, La Salteada, El Curioso, Meseta Cuadrada, Sierra Cuadrada Norte and Sierra Cuadrada Sur, hosted by sedimentary rocks and Cerro Chivo, hosted by volcano-sedimentary rocks. Different stages of surface exploration are being performed in these areas. Mineralized areas Laguna Sirven and Primavera, calcrete-type of mineralization, are being explored by means of trenches.

Advanced seismic techniques applied to structural characterization of mine development sites

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Mineral deposits are often hosted in deep geological features with variable dimensions and shapes, diverse orientations and complex physical properties. This combination of large depth and high variability is a challenge for the structural characterization of these deposits and their surroundings, especially when meter or sub-meter resolution is required. 3D seismic surveys are performed by deploying overlapping rectangular grids of sources and receivers on the ground surface, their primary goal being to image the horizontal and gently dipping bedding sequence beneath. Steep faults are however only inferred indirectly by surface 3D. With VSP (Vertical Seismic Profiling), receivers are placed in boreholes and sources are deployed on surface. The vertical receiver arrays permit steeply inclined targets to be imaged directly, while the resolution increases because of the shorter distances from targets to receivers. Significantly more resolved - albeit also more local - images are obtained by Side-scan seismic surveys, with sources and receivers placed in the same borehole. These three techniques were applied jointly within a pre-feasibility study for mine development of the Millennium uranium deposit, in the Athabasca basin of northern Saskatchewan, Canada. The zone of interest is located at 600 m depth in graphitic fault zones within the upper basement overlain by quartz-rich sandstones. A novel 3D imaging technique, the IP-3D pre-stack migration, that can integrate uneven combinations of surface and borehole seismic layouts has been used. The defining property of the IP (Image Point) migration is its ability to resolve images of targets of diverse orientations while strongly suppressing 'smiling' artifacts characteristic to unevenly covered layouts. Sharp 3D images of both bedding and faults are obtained by this novel technique, which increases significantly the level of detail and interpretability of the imaging exercise.

Uranium and REE resources of South Eastern Desert of Egypt

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Abu Rusheid- Sikait area (ASA) is located at the south Eastern Desert of Egypt, 50 km southwest of Marsa Alam from the Red Sea coast. Two nappes are common; ophiolitic nappe (mafic – ultramafic rocks) and arc assemblages nappe (metapelites, cataclastics, metavolcanics and tonalite rocks) separated by mélangé rocks. The cataclastic rocks in Abu Rusheid (3 km²) are classified into protomylonite, mylonite, ultramylonite and quartzite with gradational contacts. Quartzites (1.8 Km in length, 100-400m in width) are predominant in Sikait area. ASA is traversed by good channel-ways represented by strike slip faults trending ENE-WSW, NNW-SSE, N-S and NNE-SSW.

Two brecciated discontinuous shear zones (NNW-SSE and ENE - WSW) crosscut the cataclastic rocks. Lamprophyre dykes (0.5-1.0 m in width, 0.5-1.0 km in length) bearing mineralization (e.g. REEs, Zn, U, Cu, Sn, W, Ni & Pb) were emplaced along the shear zones. Uranium contents range from 500-1500 ppm. Uranium minerals (uranophane and beta-uranophane, kasolite, torbernite, autonite and meta-autonite) in addition to columbite, sulfides and molybdenite are common in quartzites and lamprophyre dykes, whereas uranophane and uranothorite are coating the foliation planes in Abu Rusheid cataclastic rocks.

The lamprophyres have abnormal abundance of REEs (up to 1.5%) with average $\Sigma\text{LREE}/\Sigma\text{HREE}$ ratio equal to (0.14). The HREE enrichment is attributed to some heavy minerals (e.g. xenotime, fergusonite, zircon and fluorite). The lamprophyre average samples are characterized by reverse fractionated REE patterns [(La/Yb)_N = 0.12] and pronounced negative Eu anomalies (Eu/Eu* = 0.08) with HREE enrichment [(Gd/Lu)_N = 0.80]. The lamprophyres are mantle-derived and enriched by Co² and volatiles. Alteration processes (illite, smectite, hematitization, sulfidization, silicification and fluoritization) acts as physical and chemical traps for all mineralization.

Spatio-temporal distribution of uranium deposits in Mesozoic – Cenozoic Era in China

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Over 90 percent of the uranium deposits including the most important granite type deposits, volcanic and caldera-related deposits and sandstone deposits in China have been discovered in Mesozoic-Cenozoic Era. Spatially, there are five uranium metallogenic provinces dominated by South China uranium metallogenic province in South-East China and Tianshan uranium metallogenic province in North-West China.

The granite type deposits are mainly located in South China uranium province with the mineralization ages of 100 Ma – 137 Ma and 47Ma – 87 Ma respectively. Current studies indicate that uranium deposits with the mineralization ages of 100 Ma -137 Ma, normally characterized by relatively high temperature mineral assemblages such as uraninite associate with scheelite and tourmaline, have been considered as the early stage uranium mineralization in South China, which is the main exploration target currently in South China. Uranium deposits characterized by quartz-pitchblende veins in host granites with the ages of 47 Ma-87 Ma are the typical granite type uranium deposits in South China, Xiazhuang uranium ore field for instance. The host rocks are traditionally considered as the intrusive granites of Yenshan epoch. However, new isotopic dating results show that most granite hosting both early or late stage uranium deposits in South China are the intrusive rocks of Indo-Chinese epoch with the age of granites large than 200 Ma.

Xiangshan is the biggest uranium ore field dominated by volcanic and caldera-related deposits in South China uranium metallogenic province. Two stages of uranium mineralization have been identified including the early alkaline hydrothermal mineralization of 115.2 ± 0.5 Ma and the late acid hydrothermal mineralization of 99.0 ± 6.0 Ma. While the host rocks including rhyodacite and porphyroclastic lava dated of 140 Ma to 158 Ma.

Sandstone type uranium deposits are mainly distributed in Tianshan uranium metallogenic province, such as the deposits in Yili Basin, and in the new exploration areas of Erdos Basin and Er'lian basin. Although there are many publications about the mineralization ages of sandstone type uranium deposits which cover a wide range of ages from 8 Ma to 120 Ma, it is necessary to reveal the main mineralization ages by up-to-date isotopic method.

Since large scale mineralizations of nonferrous metal, precious metal and rare metal also took place in Mesozoic- Cenozoic Era, as the natural element, uranium deposits have been regarded as one of the members of mineral resources of minerogenetic series closely related to the tectonic - magmatic evolution in Mesozoic-Cenozoic Era in the mainland of China.

Interlayered oxidation mineralization of uranium in Sandstone: A case from Bayanwula, Erlian Basin, Inner Mongolia, China

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Bayanwula sandstone-type uranium deposit in Manite subbasin, Erlian, is a new successful example explored with the theory of interlayered-oxidation zone introduced into China from the Central Asia countries. Based on the predecessor's achievements, this paper carried out field investigation, observation of drilling cores, analyses of gamma, resistivity and spontaneous potential curves. It is demonstrated by logs and core observation that the target layer for uranium mineralization is mainly the late Early Cretaceous Saihan Formation (K_{1bs}) which is the multi-episodic superimposed braided river channel deposits. The metallurgic system consists of upper mudstone aquitard, Saihan permeable conglomeratic sandstone and lower Tenggeer (K_{1bt}) lacustrine impervious mudstone/shale. The uranium mineralization is closely related to the lateral oxidation, i.e., U-O- bearing fluids originated from the northwest uplift flow southeastward into the Saihan sandstone and cause yellow oxidation and alteration of host rocks. The fluids reduced by carbonized plant fragments, pyrite or/and "asphaltite" (?), then, U^{6+} in the oxidized fluids is reduced into U^{4+} and precipitates and enriches. The microscope and probe analyses show that uranium in the deposit is in the form of independent minerals or/and absorption by organisms and titanium oxides, such as coffinite, uranothorite, uranium black, uranium phosphate / carbonate.

The main geological types of uranium deposits in Argentina

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The uranium-related activities in Argentina began in the 1950s and, as a result of the systematic exploration, several types of deposits have been discovered since then: volcanic and caldera-related, sandstone-hosted, vein spatially related to granite (intragranitic and perigranitic) and surficial.

The deposits those which have been objectives of the most important uranium exploitations are the ones that belong to the volcanoclastic type, which are localized in Permian formations associated with synsedimentary acid volcanism in the Sierra Pintada district (Mendoza province). The current identified resources are 4 420 t U recoverable at a cost below US\$130/Kg U.

Several important uranium mineralisations have been identified in Cretaceous fluvial sandstones and conglomerates, among which the most relevant is the Cerro Solo deposit (Chubut province). The mineralized levels there are 0.5 - 6 meters wide and 50 – 130 meters deep. The identified resources totalise 11 220 t U at 0.4 % U, included in the < US\$130/Kg U cost category.

The uranium mineralisations in veins and disseminated episyenites within peraluminous leucogranites of the Sierras Pampeanas (Cordoba and San Luis provinces) represent other types of existing deposits. These granites are Devonian – Carboniferous and the related deposits are comparable to those from the Middle European Variscan chain.

There is also another vein-type uranium deposit located in a metamorphic basement in the periphery of high potassium calcalkaline granites (Las Termas deposit, Sierras Pampeanas Noroccidentales, Catamarca province). The mineralization control is mainly structural and the speculative resources have been evaluated in 1 500 t U at a grade of 0.3% U.

More recently, the pedogenetic calcrete type has been studied in the area of Laguna Sirven (Santa Cruz province). The speculative resources there are about 1 000 – 1 500 t U at 200 ppm U.

Finally, it can be pointed out that the existence of favourable basins and different uranium mineralization models configure promising conditions to develop new uranium resources. In this context, the uranium deposits related to continental sandstones appear as the most interesting exploration targets in the country.

Uranium exploration and exploitation in Mozambique - past, present and future

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Uranium has been explored since 60th years and was exploited in underground mine in the 60th years in the north province, Tete. It was a small mine with two shafts about 80m deep. The Production stopped in later 60th. No remediation work has been done, the shafts are still open and the area contaminated. No, radiation control is in place. A project is in place to recall the failures for the past through an adequate regulatory framework and its enforcement.

At this moment are two projects in exploration phase running in the sandstone bearing uranium rocks in Tete and Niassa provinces. Geophysical and geochemical airborne have been done and drilling is in place, the results are promising.

The projects cover the sandstone of the upper Karoo Super group. In Mucumbura area, the upper Karoo is underlain by more argillaceous sediments and coal measures of the Lower Karoo and is overlain by cretaceous sediments and in Zumbu the upper Karoo sandstones overlap the lower Karoo to sit directly upon ancient, metamorphic basement rocks and there appears to be cretaceous cover

The target is the sandstone hosted uranium mineralization within the upper Karoo of a similar type to that of the Kanhamba deposit (Zimbabwe), Mutanga-Dibwe (Zambia), Kayalekeera (Malawi) and Mkuji River (Tanzania)

This project cover the upper Karoo sediments that are recognized in the adjacent countries of Tanzania and Malawi to host significant uranium mineralization.

Uranium mineralization in late cretaceous sandstones in parts of Meghalaya, India

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Late Cretaceous Lower Mahadek sandstone of Meghalaya has been established as the potential host rock for sandstone type of uranium mineralization in India. Till date nearly 16 000 tonnes of U₃O₈ reserves have been estimated in four locations viz., Domiasiat, Wahkyn, Tyrnai and Lostoin, in the southern part of Meghalaya plateau. The uranium investigations are primarily confined to in the areas where the Lower Mahadek sandstones are exposed either on the surface or along deep river cuttings, otherwise concealed by thick cover of Tertiary sediments. The area poses major logistic challenge due to thick forest and remoteness. Out of nearly 1 800 km² of extent of the Mahadek Basin, only 28% of the area exposes Lower Mahadek sediments.

Survey in recent years has also established few more occurrences at Umthongkut, Wahkut and Rongcheng Plateau in Balphakram area. Systematic study of available surface and subsurface data has revealed that mineralization is controlled by palaeo channel configuration of Mahadek sediments and also the typical geochemical interface. Regional and local tectonics also have played an important role in distribution and concentration of uranium mineralization in the area. It is observed that the deposits and the very promising occurrences described above fall strikingly along an E-W lineament. Litho-structural studies indicate that the southern block appears to have gone upwards relative to the northern block in contrast to other such signatures in the area. This might have influenced ground hydrodynamic flow pattern and helped in concentration of uranium.

The Lower Mahadek sandstones, host rock of these deposits are mostly sub-arkosic to arkosic, grading sometimes to felspathic arenite. The main uranium minerals are pitchblende, coffinite and organo-uranyl complex. Uranium mineralization is associated with bituminous organic matter occurring as dense inclusions, isolated clusters and lumps of various sizes and as clayey – dusty organic matter associated with cementing material. The work so far has been confined to the shallower part of the basin (28% of the total area). There is no reason to believe why many more concealed deposits in remaining 72% of unexposed Lower Mahadek sediments may not be present.

Geophysical investigations, mainly magnetic survey is in progress in some identified blocks in the area between Wahkyn and Umthongkut which are otherwise covered by 300-400 m thick Tertiary sediments. Such surveys would help in delineating magnetic lows which otherwise indirectly points to the presence of buried palaeochannel. Integrated Remote Sensing studies using high resolution satellite data of IRS LISS-III and LISS-IV are being undertaken to delineate broad lithological and structural patterns between Umthongkut and Wahkyn. The role of neo-tectonics in disposition of Lower Mahadek sandstone is being evaluated prior to taking up deeper subsurface exploration. Thus, the Lower Mahadek sandstones covered by thick Tertiary sediments in the larger part of the Mahadek basin are being probed by indirect techniques in order to discover more sandstone type of uranium deposits in Meghalaya.

Proterozoic unconformity related uranium mineralization in the Srisailam and Palnad Sub-Basins of Cuddapah Basin, Andhra Pradesh, India

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The intracratonic, Mid-Proterozoic Cuddapah Basin has been identified as one of the promising targets for locating unconformity related uranium mineralization in India. On the northern part of the basin lie two subbasins namely Srisailam and Palnad with arenaceous, argillaceous and carbonate sediments resting on basement rocks of granitoid, basic dykes of lower Proterozoic age and narrow linear greenstone belt of Archaean age. Exploration in the northern part of Srisailam subbasin has established three small tonnage, medium grade uranium deposits namely Lambapur, Peddagattu and Chitrial. Exploration effort in the northwestern margin of Palnad subbasin has yielded uranium deposit at Koppunuru. Srisailam subbasin comprises pebbly quartzite, quartzite, purple to grey shale. Uranium mineralization is mainly confined to the fractured basement granites close to the unconformity, with shallow depth persistence. These deposits occur as elongated pods at the intersection of N-S, NNE-SSW and NW-SE trending prominent sets of fractures along the unconformity. Uraninite is the main primary phase identified in these deposits and is closely associated with drusy quartz, galena, chalcopyrite and pyrite. Illitization and chloritization are the common alteration features observed. Intergranular fracturing and granulation of quartz and feldspar favoured the circulation and concentration of uranium. Totally around 14 000 t U_3O_8 with a grade of 0.070 U_3O_8 , has been estimated in three deposits of Srisailam subbasin. Palnad subbasin consists of arenaceous, argillaceous and carbonate sedimentary sequence. In Koppunuru uranium deposit three distinct uranium mineralized bands hosted by quartzite/ shale, gritty quartzite and altered basement granites have been delineated. Pitchblende, coffinite and mixed phases of U, Ti, Si are the uraniumiferous phases. Uranium in variable concentrations is also associated with sericite, clay, glauconite, chlorite and biotite. Pyrite and carbonaceous matter are intimately associated with uranium mineralization. Mineralization occurs in the form of fine veins, fractures, cavity and grain boundary fillings. Around 2 300 t U_3O_8 with a grade of 0.11% U_3O_8 has been estimated in Koppunuru uranium deposit.

Intensive exploration on similar models in contiguous areas resulted in locating several uranium occurrences. Significant among them are the Amrabad and Akkavaram outliers of Srisailam subbasin and Musi river sector of Palnad subbasin. The southward continuity of the litho-structural setup of Lambapur, Peddagattu and Chitrial uranium deposits outliers and the favorable criteria, such as the lower Proterozoic fertile fractured granitoid basement, middle to upper Proterozoic cover rocks and repeated phases of tectonic activity, indicate that the main Srisailam subbasin may host large tonnage and medium grade deposits. Similarly the southern part of the Palnad subbasin also holds promise for locating unconformity related uranium deposits.

Proterozoic stratabound carbonate rock (dolostone) hosted uranium deposits in Vempalle formation in Cuddapah basin, India

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The Cuddapah Basin situated in the eastern part of the Dharwar Craton is one of the major Proterozoic, intra-cratonic, sedimentary basin in India. Cuddapah basin covers an area of 44 000 sq.km. with a total estimated stratigraphic thickness of nearly 12 km. Lithostratigraphically, the sediments in the Cuddapah basin are divided into the Cuddapah Supergroup and the overlying Kurnool Group. The Cuddapah Supergroup consists of three Groups, namely Papaghni, Chitravati and Nallamalai, wherein Papaghni group is oldest. This paper deals with the stratabound carbonate (dolostone) hosted uranium mineralization in Vempalle Formation of Papaghni group in the southwestern part of the Cuddapah basin. Uranium mineralisation extends from Reddipalle in the northwest to Maddimadugu in the southeast over a belt of 160 km, with promising mineralisation at Tummalapalle, Rachakuntapalle, Giddankipalle and Kanampalle in the central part. Out of 160 km, only about 9.5 km belt along the strike and 1 to 2 km along the dip in Tummalapalle-Rachakuntapalle tract is explored by drilling wherein 29 000 tonnes of uranium oxide contained in about 61 million tonnes ore of 0.05% eU_3O_8 average grade. Continuity of the similar geological setting and surface expression of mineralised outcrops with higher uranium concentration (upto 0.56% U_6O_8) all along the unexplored areas indicate its potentialities for establishing larger and low grade uranium deposits in the extension areas.

Uranium mineralisation occurs along the bedding planes as two bands, hangwall band and footwall band with a vertical separation of 1 m to 5 m. Both the bands show isotropic character along and across the strike in terms of grade, thickness and metal content. Presence of primary sedimentary structures like mud cracks, ripple marks and abundant algal stromatolites associated with mineralized bed indicate a shallow marine environment of deposition. The uniformity in thickness of ore body, large lateral extent of the mineralization, absence of a hydrothermal vent, associated alteration and lack of kinks in mineralised band suggest a diagenetic origin by sedimentary processes for this deposit. Uranium mineralisation is hosted by impure siliceous phosphatic dolostone. Megascopically the mineralized dolostone consists of alternating light to dark grey coloured thin layer consisting of fine to coarse grained dolomite, ultrafine collophane, and detritus component consisting of quartz, feldspar, tourmaline, zircon and monazite. Petrographically the uranium minerals identified are ultrafine pitchblende, coffinite and U-Si-Ti complex. The associated sulphides include pyrite (As and Ag bearing,) molybdenite (Mo-oxide), chalcopyrite (Cu-Fe sulphide), bornite (Cu-Fe sulphide), digenite and covellite (Cu-sulphide). The chronology of U-mineralisation and minimum age for carbonate sedimentation and dolomitisation is estimated to be $1\ 756 \pm 29$ Ma by Pb-Pb method.

Prospects and potentialities for uranium in North Delhi Fold Belt: A case study from Rohil, Rajasthan, India

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North Delhi Fold Belt (NDFB) of Western Indian Craton consists of Paleo-Meso Proterozoic volcano-sedimentary Delhi Supergroup of rocks deposited in half graben structures. They have undergone polyphase deformation and varying metamorphic grades and are intruded by granites representing culmination of Delhi Orogeny. Late phase pegmatite, aplite and albitite have been emplaced along major structural breaks in these rocks.

The NDFB comprises three sub-basins viz. western most Khetri sub-basin, middle Alwar sub-basin and eastern most Lalasot Bayana sub-basin. Of these, the Khetri sub-basin encompasses important uranium and base metal resources and forms an important metallogenic province. A NE-SW trending prominent crustal scale fault-fracture system, known as Kaliguman lineament, roughly separates Delhi Supergroup metasediments in the west from basement rocks in the east. A wide spread zone of albitisation along this lineament, with 170 km strike extent is popularly known as “albitite line”.

Since 1950, more than hundred U and Th anomalies, largely associated with structurally weak zones in metasediments have been reported by AMD in NDFB. One such zone at Rohil hosts a low tonnage (3 720 t U₃O₈), low grade (0.062% U₃O₈) uranium deposit. The deposit comprises five sub-vertical ore lodes occurring in en-echelon pattern over strike extent of 340-686m with av. thickness of 4.27m. The mineralisation is shear controlled hydrothermal vein type. Major uranium mineral is uraninite with minor brannerite and coffinite. Associated sulphides are represented by chalcopyrite, pyrrhotite, molybdenite and pyrite. The mineralised rocks exhibit strong hydrothermal alterations like chloritisation, silicification, ferruginisation and albitisation.

The uraniumiferous core samples of Rohil deposit analyse average U 570 ppm (n=982), Cu 1 438 ppm (n=1 185), Mo 328 ppm (n=971), Ni 193 ppm (n=1 014), Co 208ppm (n=1 078), Pb 268 ppm (n=388) and V 293 ppm (n=1 095). Preliminary Pb isotopic studies have indicated 839±12Ma age for uranium mineralisation.

At Rohil, uranium ore bodies extend below surface to 500 m depth. Coincidence of strong EM conductivity, high chargeability (>30 mV/V) and low magnetic intensity (<-250 nT) with uranium lodes have successfully guided application of ground geophysical exploration programme in contiguous alluvium covered blocks. Further, for quicker delineation of favourable targets in the Khetri sub-basin of NDFB, multi-parameter high resolution heliborne geophysical surveys have been completed over 105 km x 15km area and anomalous zones have been identified for subsurface exploration. Mathematical modeling of exploration data appears strongly applicable in effective exploration planning.

Uranium exploration in Ethiopia

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Radioactive exploration dates back to 1955 and since then little progress has been made. Few pits and trenches in some places show radioactive anomalies. The Wadera radioactive anomaly occurs within the lower part of Wadera series, Southern Ethiopia. As observed from a trench the anomalous bed has a thickness of 0.9-1.2 m and is made of reddish-grey thin bedded sandstones. The presence of Xenotime in arkosic sandstone points to the sedimentary origin of mineralization. It was noticed that the sandstone in the lower part of Wadera series has at places a radioactivity 2-3 times higher than adjacent gneisses. The presence of a placer of such a type in the Wadera series is probably a clue for the existence of larger deposits in the area.

In 2007 geological, geochemical and geophysical surveys were conducted to identify and delineate Uranium mineralization in three localities (Kuro, Kalido and Gueti) of Werri area, southern Ethiopia. Kaolinization, silicification, epidotization and chloritization are the main types of alteration associated with different units in the area. Uranium-bearing grains which are hosted in pegmatite veins and associated with magnetite/or ilmenite were observed in the three localities. Geochemical exploration accompanied by geological mapping and radiometric survey was done by employing heavy mineral concentrate, soil, chip and trench channel sampling.

Radiometric readings of total count, U, Th and K were taken using GAD-6. Soil and trench geochemical samples of the localities analyzed by ICP-MS have shown 0.1 to 3.8 ppm and 3.9 to 147 ppm Uranium and 3.5 to 104.7 ppm and 3.9 to 147 ppm Thorium respectively. Radiometric reading is higher in pegmatite veins that host Uranium-bearing minerals and some coarse grained pegmatoidal granite varieties. The areas recognized for Uranium associations need further investigations using state-of-the-art to discover economic deposits for development and utilization of the resource.

Metasomatic uranium mineralization of the Mount Isa North Block

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Proterozoic uranium deposits of the Mt Isa North Project are centred 40 km north of Mt Isa, NW Queensland. Regionally, the deposits occur within the Leichhardt River Fault Trough of the Mt Isa Inlier. Uranium mineralisation is likely related to the 1 600-1 500 Ma Isan Orogeny. Structurally-controlled uranium mineralisation is preferentially hosted in greenschist facies basalts and interbedded clastic sediments of the Eastern Creek Volcanics (ECV). Uranium deposits of the Mt Isa North Project are defined by the following general characteristics:

- Pervasive sodium and calcium metasomatism, expressed as red albitite with finely disseminated hematite and calcite, with distal zones of chlorite and magnetite.
- Uraniferous albitite deposits typically comprise en echelon lenses and shoots.
- Mineralisation is developed along N- to NE-striking shear zones with associated brittle deformation of the host lithologies.
- Host rocks are mostly basalt flows with flow-top breccias and interbedded sandstones and siltstones of the ECV; quartzites are also locally mineralised.
- Geochemically the deposits are characterized by enrichment of U, Na, Ca, Sr, Zr, Th, Hf and P, and depletion of K, Ba, Rb and Cs. Uranium mineralogy of albitites comprises several phases of refractory uranium minerals (e.g. brannerite, coffinite).

The Mt Isa North Project includes 11 tenements being explored for uranium by Summit Resources. Summit's five uranium resources total 95.7 Mlb U₃O₈. Scoping studies focused on geologic assessment, environmental baseline monitoring and metallurgical test work of the Valhalla deposit are in progress.

Summit is in a 50/50 Joint Venture with Paladin on the Valhalla and Skal deposits. Paladin also has a direct ownership of 81.99% of the issued shares of Summit Resources.

Nuclear Materials Authority (NMA) activities in exploring its uranium resources, Egypt

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NMA was initiated as the Geology and Nuclear Raw Materials Department in the Atomic Energy Authority of Egypt (established in 1957). However, due to the extended nature of NMA's work and its increasingly expanded activities in the fields of prospection, exploration and evaluation of nuclear raw materials required for the peaceful uses application of nuclear energy, beside processing of their ores; this Department was converted into a separate authority; namely the Nuclear Materials Authority (NMA) of Egypt, in 1977. Since several decades, Egypt started prospecting and regional exploration for radioactive raw materials using Airborne and ground surveyes, carborne, and field reconnaissance in soft and hard rocks During this work activities, some promising U-occurrences were discovered. Airborne radiometric survey started in Egypt in 1958; The International Atomic Energy Agency (IAEA) cooperated with NMA in 1998 for the construction of 4 sets of calibration pads for standardizing both aerial and ground survey instruments. Application of all these activities resulted in completing aerial radiometric prospection of about 40% of the Egyptian territories, among which some locations were also magnetically surveyed from the air. NMA organized several ground geophysical and geological expeditions to verify the registered anomalies, discover any possible mineralization and identify the promising locations using electric, electromagnetic, self-potential, induced polarization, radon, seismic, gravity, ets In the meantime, the necessary relevant field geologic studies were undertaken, together with site development works, involving percussion and core drilling. Geophysical well logging measurements, beside excavation works of some exploratory mining tunnels were conducted. The before mentioned activities led to the definition of three encouraging uranium occurrences in the granite; and metamorphic rocks of the Eastern Desert of Egypt and a fourth occurrence in the sedimentary rocks of west Central Sinai these are: Gabal Qattar, occurrences (Northern Eastern Desert). Al-Missikate, and Al-Aradya occurrences, (Central Eastern Desert). Abu-Russhied, Seila, and Um-Ara occurrences, Southern Eastern Desert. Abu-Zeneima occurrences (west Central Sinai). These represent the main occurrences of Uranium resources which were variably developed by NMA, in addition to some other less-important uranium localities. These occurrences could be classified into conventional uranium resources, and non-conventional uranium resources (uranium production is a by-product). NMA undertaken different ore processing studies for the discovered mineralizations and was actually able to design several technological flow sheets for the preparation of uranium concentrate (yellow cake). NMA erected two experimental units for uranium recovery at Abu-Zeneima, and Qattar respectively; The preparation of yellow cake was executed using acid heap leaching, followed by uranium extraction with anion exchange resin. Kilograms of uranium concentrate (yellow cake) were prepared by such two units. NMA is also undertaking various works for the purification of the uranium concentrate (yellow cake) obtainable from the different experimental units whether from that at Inchass or from the two field experimental units at Gebel Gattar Abu Zeneima sites. Airborne surveys, recently conducted by NMA over the Mediterranean coast, demonstrated their use as a powerful tool in evaluating mineral of beach mineral sand deposits. The most important economic minerals are: ilmenite, magnetite, zircon, garnet, rutile and monazite. NMA started, since the year 2000 a detailed evaluation of the black sands at AL-Burullus – Balteem, Northern coast which could offer more than 200 million tons as reserves.

Uranium prospection in Venezuela

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The worldwide increase of energy consumption and high fossil fuels costs generates the necessity of alternative energy sources. At present, nuclear energy is substituting the use of hydrocarbons, due to its high performance and contribution to environmental preservation, since it avoids the emission of greenhouse gases. Uranium consumer countries will continue to increase its demand, and even, is expected the incorporation of new reactors in countries with emerging economies. Base in the statement considered above, investment in new mineral deposit is justified. At present, some countries are motivated to start or continue the uranium exploration because of the evolution of the nuclear energy industry. Venezuela started exploration in the mid of 1970s, and stopped at 1980s. Our purpose is to evaluate uranium resources potential in the country, both for own use or export. In order to locate potential areas for exploration, in this initial phase all data from previous period it is being compiled incorporating information from oil exploration (seismic data, wells profiles, etc.). This information is been digitalized to generate a database into a geographical information system. Preliminary results show three areas of interest, where new geological, geochemical and geophysical surveys are propose. At this time, we do not have specific information about ore reserves, but we have anomalous areas that have been established as starting points to continue the uranium exploration in the country.

Uranium prospection in Uruguay

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The strategic policies in the energy area defined in Uruguay for the period 2005 – 2030, do insist in the searching of energetic independence, in a framework of regional integration, according with economically and environmentally sustainable policies, for a productive country, taking into account social involving. The search of energetic alternative in Uruguay has driven us on one side to develop the first experiences of the incorporation of renewable energy sources, and on the other side to renew the activities of searching of native fuels, group in which Uranium is included. This initiative is actually the continuation of important efforts developed by the Uruguayan Estate for 40 years, which started in 1949. Although the prospecting and mining exploration works have been conditioned by the lack of proper geological-structural information, and the technology available at that moment have been useful at the moment of concluding about the importance of continuing these efforts. During the year 2007 it has been developed a call for expression of interest for the developing the activities of Prospection – Exploration, Mining and Production of Uranium. Through this media there has been received a set of proposals that led us to consider it a success. This work is presented in a brief compilation of the background that have been used as a starting point for the determination of the geographical areas where there will be a continuation of activities tending to complete the prospection of Uranium and other radioactive minerals. Apart from this. A brief presentation of the conditions of the calling that will be carried out during the 2009 for the develop of activities of prospection of Uranium and other radioactive minerals is presented.

Uranium resources of Niger

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After the discovery of the first uranium shows in Niger in 1958 by the BRGM (Bureau de Recherche Géologique et Minière) at AZELIK, the French CEA (Commissariat à l'Energie Atomique) has carried out a systematic and detailed exploration program from 1959 to 1980 throughout the Tim Mersoï basin (140 000 km²), leading to the discovery of many other uranium shows and deposits among which, fifteen are worldwide scale. Two other Paleozoic basins (Djado and Emi Lulu) have also a good uranium potential. In 1971, SOMAIR (Société des Mines de l'Air) began uranium production, followed in 1978 by the COMINAK (Compagnie Minière d' Akouta), they have produced 110 000 tU. During the first uranium boom (1973-1980) several mining and oil companies (Cogema, Conoco, Pan Ocean, BP, Esso, OURD, IRSA, and PNC) have obtained licenses for Uranium research in Niger. Many uranium shows have been identified, explored and evaluated. The deposits of economic interest are: Arlette, Ariège, Taza, Tamou, Takriza, Artoi, Tabelle, Imouraren, Irhawenzegirhan, Azelik, Madaouela, Ebene, Akouta, Akola, Ebba. Following a spectacular increase of uranium price and demand, the research that has been interrupted for more than a decade have resumed from 2002: 127 exploration permits have been granted to some fifty mining companies in Niger.

All economic mineralizations are located in detritic sedimentary formations (conglomerates, sandstone, and siltstones) rich in organic vegetable matters and sulphides, of Carboniferous to Cretaceous ages. In addition to the sedimentological and stratigraphic control, the redox phenomena and tectonic evolution of the northern Niger region played an important role in the occurrence of various deposits. In the Tim Mersoï Basin uranium is essentially found in its proper mineralogical forms, out of which the main identified are primary minerals of pitchblende - uraninite group and coffinite. Its occurrences in the crystalline network of clay minerals and other products are rarely observed. Meanwhile, at Imouraren and Azélik the secondary minerals (gummite, uranotile, tyuyamunite autunite) predominate. The average grade of the economic deposits varies from 0.08% U and 0.6% U. The depths range from 0 to 265 m.

Despite the 110 000 tU extracted during the past 40 years, considerable global resources evaluated approximately at 500 000 tU still remain in Niger, shared out as follows: 300 000 tU of reasonably assured and economically recoverable resources, 200 000 tU of estimated additional resources. The speculative resources could double. The exploitation of Imouraren uranium deposit (230 000 tU recoverable) and Azélik (13 700 tU) is in process. Near the Arlit lineament and its satellite faults, detailed exploration work using new methods with more efficiency would give rise to the discovery of other deposits around many existing uranium shows in the following licenses: Madaouela, Adrar Imola, Afasto, Toulouk, Terzemazour, Tagaït, Abelajouad, Asamaka, Agelal, Zelin, Tin Négourane, Téguida, Irhazer and In Gall. Niger is about to become the second worldwide uranium producer both in term of production and resources and could, at the current production rate, maintain its ranking for several decades.

The giant Kvanefjeld specialty metals project, Greenland: A future uranium supplier

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The Kvanefjeld Project is located near the southern tip of Greenland, and is now recognised as one of the largest undeveloped deposits of rare earth elements (REEs) and uranium in the world. The project was originally investigated as a potential uranium resource by the Danish Government through the 1970s and early 1980s before work on the project ceased owing to the negative sentiment that emerged toward nuclear energy globally. The Kvanefjeld project lay dormant for over twenty years until it was acquired in 2007 by Greenland Minerals and Energy; an Australian-based exploration and development company that set out to evaluate Kvanefjeld as a polymetallic resource, rather than as a single commodity operation. This approach was fuelled by: 1) the steady increase in demand for rare earth elements, owing to their essential requirement in many new technologies that will soon be common consumer items; 2) recognition through academic studies that Kvanefjeld could contain vast quantities of specialty metals; and 3) a nuclear renaissance owing to growing concerns over the environmental impact of carbon-based energy sources. Collectively, rare earth elements and uranium can be considered as strategic commodities, with long term forecasts highlighting increasing demand with looming supply shortfalls. Following the first drill program undertaken by Greenland Minerals and Energy, the company released a first multi-element resource estimate that complies with the Australian Joint Ore Reserves Committee (JORC) requirements. This initial resource statement includes 223 million pounds of uranium (at 302 ppm uranium oxide), and 2.6 million tonnes of rare earth oxide. The resource is expected to grow significantly following a 20 000 m drill program in 2008. It is now clear from recent exploration that Kvanefjeld is rapidly emerging as a world class specialty metals project that could be the largest supplier of rare earth elements outside China, and a globally significant uranium producer. The path to development for the Kvanefjeld project is closely tied to political developments in Greenland. In a referendum in late 2007, Greenland voted strongly in favour of independence from Denmark. With independence comes recognition that expanding its mining industry is essential to developing a robust economy, which is currently dependant on Danish subsidies. Following the referendum, a parliamentary debate was held on Greenland's stance on uranium exploitation, which is one of zero tolerance. The debate concluded that by-product uranium production from polymetallic ores should be considered, to allow projects such as Kvanefjeld to advance to development.

Uranium Mining & Processing

Elkon – A new world class Russian uranium mine

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The uranium deposits of Elkon district are located in the south of Republic of Sakha Yakutia. Deposits contain about 6% of the world known uranium resources: 342 409 tonnes of in situ or 288 768 tonnes of recoverable RAR + Inferred resources. Most significant uranium resources of Elkon district (261 768 tonnes) were identified within five deposits of Yuzhnaya zone. The uranium grade averages 0.15%. Gold, silver and molybdenum are by-products. Principal resources are proposed to be mined by conventional underground method.

Location, shape and dimensions of uranium ore bodies are primarily controlled by NW-SE oriented and steeply SW dipping faults of Mesozoic age and surrounding pyrite-carbonate-potassium feldspar alteration zones. Country rocks are Archean gneisses. Deposits are of metasomatic geological type. Principal mineralization is represented by brannerite.

The Yuzhnaya zone is about 20 km long. It was explored by underground workings and drill holes. Upper limit of ore bodies is at a depth of between 200 m and 500 m. Depth persistence exceeds 2 000 m.

Uranium mining enterprise Elkon was established in November 2007. It is a 100% Atomredmetzoloto subsidiary. The planned producing capacity is 5 000 m tU/year. It will perform the entire works related to uranium mining, milling, ore sorting, processing and uranium dioxide production.

Technology of ore processing assumes primary radiometric sorting, thickening, sulphide flotation for gold concentrate extraction, subsequent autoclave sulphuric-acid uranium leaching from flotation tails and uranium adsorption onto resin, roasting and heap leaching for uranium from low grade ores, cyanide leaching of gold. Due to a considerable abundance of brannerite ore is classified as refractory.

Elkon development include 4 main stages: feasibility study and infrastructure development (2008-2010), mine and mill construction (2010-2015), pilot production (2013-2015), mine development and achieving full capacity production (2016-2024).

Licensing status of new and expanding in-situ recovery uranium projects in the United States

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The authors investigated the licensing status of new in-situ recovery (“ISR”) uranium projects, as well as the expansion of existing projects, within the United States (“US”). Specific emphasis and analysis is placed on those projects within the states of Texas and Wyoming. Of note, information used to prepare this paper was obtained from public sources that included company web sites, the US Securities and Exchange Commission, the US Nuclear Regulatory Commission (“NRC”), the US Energy Information Agency (“EIA”), and the relevant state regulatory agencies.

The renewed interest in the production of natural uranium has been motivated, in part, by the increased sale price of yellowcake beginning around 2003 resulting in numerous new and existing natural resources companies acquiring mineral rights in the United States. Because of the economic favorability in terms of both operating and capital costs of ISR mines versus conventional mines in the US (with its relatively low grade of uranium ore), the model for most companies was to acquire mineral properties that had the potential for being mined using the ISR method. There were, however, exceptions to this model. The Uravan mineral district in southwest Colorado and southeast Utah, where relatively high-grade, shallow uranium deposits have the potential to be mined using underground methods, is one such exception. However, the focus of this paper will be on ISR projects.

In Wyoming, which has been the top producer of natural uranium among the 50 states for the past seven years, there is one producing ISR mine (Bill Smith - Highland), one ISR mine on standby (Christensen Ranch), and two ISR uranium projects licensed but not yet built (Gas Hills and North Butte). Cameco Resources is planning to develop two ISR projects in Wyoming that have been licensed but not yet constructed. Additionally, three new uranium companies (Ur-Energy, Uranerz and Uranium One) have filed applications with the federal and state agencies to construct and operate commercial uranium ISR mines on their respective properties in Wyoming.

The only other states that have had, and currently have, commercial ISR uranium production are Nebraska and Texas. According to the EIA, in 2008 there was production from one ISR mine in Nebraska and from four ISR mines in Texas. Applications are pending for expansion of the Crow Butte mine in Nebraska, and applications are also pending for both a new ISR mine and expansion of at least one existing mine in Texas. Nebraska, like Wyoming, is a non-agreement state requiring both state and federal operating licenses for an ISR uranium mine while Texas is an agreement state requiring only a state license for operating an ISR mine. In addition to the aforementioned states, ISR development plans and licensing status of projects in Colorado, New Mexico and South Dakota will also be covered in this paper.

Uranium potential and socio-political environment for uranium mining in the eastern United States of America with emphasis on the Coles Hill uranium deposit

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The United States of America is the world's largest consumer of nuclear power with 104 operating stations that produce almost 20% of our nation's power supply. In 2007, the US nuclear power plants generated 806.5 billion kWh while France that gets 77% of its electricity from nuclear energy has 59 operating stations generated 418.6 billion kWh. In 2007, according to the US Department of Energy (DOE), the United States purchased 51 million pounds of U_3O_8 of which only 8% (4 million pounds) was US origin and the remaining 92% (47 million pounds) from foreign sources. The DOE projects that US electricity demand will rise 25 percent by 2030.

Virginia Uranium, Inc. is focused on the exploration and development of the Coles Hill Uranium Property which is believed to contain significant deposits of uranium and in Pittsylvania County, Virginia. The area was favorable due to the existence of boundary Triassic Basins in contact with local high background granites. The deposits consist of continuous high grade zones (greater than 0.25%) within and along a central axis with decreasing grade outward. There is considerable potential to both extend the high-grade sections within the overall deposit and extend the deposit at depth. In addition, a number of exploration targets have been identified in the surrounding land package controlled by Virginia Uranium. At this time, the project is ready to move to a pre-feasibility stage and will need a state-regulatory framework to move the deposit to a reserve and full feasibility stage. The defined deposit comes to the surface and is amenable to open pit mining. In addition to the two deposits there are other highly prospective areas in Pittsylvania County that deserve further exploration. In 1982, the project contained sufficient "reserve" estimates for the Commonwealth of Virginia to hold hearings and establish the Uranium Administration Group (UAG). The UAG was charged with examination of uranium development at Coles Hill and 17 of the 19 members supported the development of regulations for uranium mining. Regulatory permitting process delays extended into the 1980s downturn in the uranium market and nuclear industry, and the project was abandoned, with leased mineral rights eventually returned to the land owners. Because the downturn in prices made uranium development uneconomic, Uranium mining regulations were never recommended by the UAG. The recent return of higher uranium prices and plans for the nuclear renaissance restarted interest in the deposit.

Currently, the Commonwealth of Virginia does not have uranium mining statutes or regulations, and until such regulations are developed, no permits for uranium mining can be accepted by state regulatory agencies. In September 2007, the Virginia Governor's office released the Virginia Energy Plan that stated in part "Virginia should assess the potential value of and regulatory needs for uranium production in Pittsylvania County". On the 6th of November 2008, the Virginia Coal and Energy Commission, the same organization that studied the uranium issue in the 1980s, resolved to conduct a wide-ranging study to evaluate how uranium mining, milling and tailings management can be done in Virginia so that the environment and the public are protected to acceptable risk standards.

Experience gained from the former uranium ore processing and the remediation of the site in Hungary

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Uranium ore processing started in Hungary in 1962 and was terminated in 1997 on economical reasons. The remediation of the site has started immediately and has been practically finished this year. In the poster a brief overview of the used processes, including the heap leaching will be presented including the overall remediation of the former processing site. The lessons learned both from the processing practice and the remediation will be discussed, aiming at giving supporting tools for the development of new uranium production facilities.

Main lessons are:

- for the decreasing of the volume of waste rocks to be remediated the radiometric sorting should be placed in underground if possible,
- for the heap leaching reusable pads are recommended instead of permanently expanding heaps.
- the high contamination of groundwater around the tailings ponds is the consequence of the inadequate neutralization of the barren pulp
- uranium contamination on the heap leaching site is the result of the leakage from the pipes rather than the seepage through the liner.

Results of the six years' groundwater restoration practice on tailings ponds site will be also discussed together with the estimation of the decreasing of the concentrations of the principal pollutants in the groundwater in long-term. The presentation will highlight the applicability of the geoelectrical multi-electrode measurements for monitoring of the contamination (with MgSO_4 , NaCl , CaCl_2 etc.) of the groundwater around tailings piles. The method has proved to be excellent tool for screening large areas aiming at determining the extent of the polluted area.

For the determination of the inhomogeneity of the water content in the tailings piles neutron probing method was developed. Results are important for the physical stability analyses of the tailings piles.

Results of the run of the experimental permeable reactive barrier (built in the frame of EU-sponsored PEREBAR project) also will be presented.

Underground milling of uranium ores

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This paper presents and analyzes the new concept of underground milling of high-grade uranium ore. Compared to conventional milling on surface, the underground milling scheme appears to offer significant cost savings and a lower environmental impact. The paper describes the underground milling scheme, presents process flowsheets and plant layouts, and provides an assessment of potential benefits from underground milling.

In response to the current supply/demand situation for uranium, there has been, for the past few years, a “uranium rush” in many parts of the world, including the resource-rich Athabasca basin situated in northern Saskatchewan. In a recent count, there were over forty uranium companies looking for uranium in this region. Positive results from any of these exploration activities could, depending on their location, potentially provide a source of additional feedstock for any of the existing milling centres in northern Saskatchewan and/or result in the establishment of additional new milling capacity. Underground milling would be considered in the latter instance.

The above flowsheet shows the basics of the proposed underground milling scheme, which assumes the existence of a high-grade underground uranium mine, similar to the current McArthur River mine or the planned Cigar Lake mine. Grinding, leaching, solid/liquid separation and tailings deposition are all carried out underground. Leach liquor is pumped to surface for impurity removal, precipitation and drying. The impurities, removed as chemical precipitates, are moved back underground for disposal.

Expected environmental benefits are significant and include reduction of surface visual impact, leach residues remain underground, and no tailings management facility on surface. Indeed the process residue is arguably more isolated from the environment than was the ore before mining. Contaminant transport from the stored tailings to surface waters is extremely slow. Application of membrane technology to water treatment for the underground milling scheme is expected to provide an aqueous effluent with minimal loading to the environment.

In addition to these substantial environmental benefits, underground milling is expected to give a capital cost saving on the order of 35% and an operating cost saving on the order of 30% relative to conventional mining and milling.

Converting the Caetité mill process to enhance uranium recovery and expand production

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The Caetité uranium mill, located in Caetité – Bahia – Brazil, was commissioned in 2000 to produce about 880 000 pounds of uranium oxide per year from an uranium ore averaging 0.29% U_3O_8 . The milling process starts with ore crushing followed by heap leaching with sulfuric acid solution to generate a pregnant leaching solution (PLS) containing about 2.5 g U_3O_8 /L. Uranium separation and purification is carried out by solvent extraction with a kerosene solution of tertiary amine followed by stripping with an acidified sodium chloride aqueous solution. Uranium is precipitated as ammonium diuranate that is washed, filtered and dried. The historical average uranium recovery from this process is about 76%. As the Brazilian government has confirmed recently its plans to start building the third nuclear power plant in 2009, the Brazilian uranium production will have to double its capacity in the next two years. To fulfill the increasing demand, a change in the Caetité's milling process is being evaluated in order to not only increase the production but also the uranium recovery. In the new milling flow sheet the heap leaching process is changed to conventional tank agitated leaching of a – 0.59 mm ground ore slurry in sulfuric acid medium. Batch and pilot plant essays has shown that the uranium recovery increases to about 93% under the following conditions: grind size: -0.59 mm; slurry density: 65 solids wt%; leaching time: 4 hours; temperature: 60°C; oxidation potential: ~500 mV; acid concentration in the PLS: ~10 g/L. As the use of sodium chloride as the stripping agent has presented detrimental effects in the extraction/stripping process once all the process water is recycled, two alternative process are being evaluated for the uranium recovery from the PLS: (a) uranium peroxide precipitation at a controlled pH from a PLS that was firstly neutralized with ground limestone to pH 3.2 and filtered. Batch essays have shown good results with a final precipitate product averaging 99% of purity. Conversely the results obtained from the first pilot plant essay (93 to 98% product purity) has shown that the precipitation conditions of the continuous process must be better evaluated. The pilot plant is being improved and another essay will be carried out. (b) uranium extraction with a tertiary amine kerosene solution followed by stripping with concentrated sulfuric acid solution. This extraction and stripping process is well known. Efforts are being carried out to recover the excess sulfuric acid from the pregnant stripping solution to enhance the economy of the process and to avoid the formation of a large quantity of gypsum in the pre-neutralization step before uranium peroxide precipitation.

Development and expansion of the Langer Heinrich Operation in Namibia

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The Langer Heinrich Uranium Mine (LHU) is located in the west of central Namibia, Southern Africa. It lies 80 km east of the major deepwater port at Walvis Bay and the coastal town of Swakopmund.

Designed to produce 2.6 Mlb/a U_3O_8 , LHU was the first conventional mining and processing operation to be brought into production in over a decade. The construction and staged commissioning of the project was successfully achieved on 28 December 2006 and the mine was officially opened by the President of Namibia on the 14th March 2007.

At a 250 ppm U_3O_8 cut off grade the current resource contains 32.8 Mt at 0.06% for 19 582 t U_3O_8 in the Measured category, 23.6 Mt at 0.06% for 13 276 t U_3O_8 in the Indicated category and 70.7 Mt at 0.06% for 41 557 t U_3O_8 in the Inferred category. These resources conform to both the JORC (2004) and NI 43-101 guidelines and are quoted inclusive of any ore reserves.

Ore reserve has been announced and reported conforming to both JORC and NI 43-101 guidelines. Based on the current reserve of 50.6 Mt at 0.06% for 29 874 t U_3O_8 the Project has a life of a minimum of 17 years.

The process flowsheet comprises a primary crush followed by scrubbing, size classification and recycle crushing. Minus 0.5mm from the classification circuit proceeds to leaching whilst barren material of -10mm + 0.5mm is discarded. Alkaline leaching at elevated temperature leaches the uranium into solution which is then recovered firstly by a Counter Current Decantation circuit and then fixed bed ion exchange columns. Loaded resin is stripped with sodium bicarbonate and the uranium recovered by hydrogen peroxide precipitation.

The ramp up to nameplate production was hampered early on by some mechanical and process issues all of which required technical solutions to be developed. With these in place, production now exceeds nameplate and lessons learnt have been incorporated into an expansion to 3.7 Mlb/a currently nearing completion.

Further expansion options are also being evaluated and a number of innovative flowsheet developments are under consideration, driven by a recent, large increase in the proven reserves.

This paper tracks the development of the LHU operation focusing largely on the metallurgical processes employed, some lessons learnt and considerations for the future.

In-situ recovery uranium mining in the United States: Overview of production and remediation issues

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In 2007, in-situ recovery (ISR) methods produced about 95% of U.S. production of 4.53 million pounds. Eleven new and five expansion ISR applications or letters of intent were filed with the U.S. Nuclear Regulatory Commission for the period from 2007-2009. ISR mining can be conducted in water-saturated, permeable, hydrologically confined sandstone beds where the uranium is soluble. Contamination of ground water during and after ISR operations has become a major issue for nearby residents, and for local, county and state governments. Colorado has raised ISR mining requirements and established a burden of proof that operations can return water quality to baseline conditions. Similar concerns are affecting mining plans in Wyoming, Texas, New Mexico, South Dakota, and Nebraska. Major issues affecting restoration at ISR mining operations include the following:

- Baseline water quality: Is the water presently potable or suitable for livestock or irrigation? What parts of the local aquifer should be sampled to establish baseline? What sampling methods are required to establish water quality conditions?
- Control of fluid flow during operations: How much hydrologic understanding of the ore zone is necessary to avoid flow problems?
- Ground-water restoration: To what standard should the ground water be restored? How long should monitoring occur after mining is completed?
- Ground-water restoration: What technologies work or might work?

To date, no remediation of an ISR operation in the United States has successfully returned the aquifer to baseline conditions. Often at the end of monitoring, contaminants continue to increase by reoxidation and resolubilization of species reduced during remediation; slow contaminant movement from low to high permeability zones; and slow desorption of contaminants adsorbed to various mineral phases. New remediation technologies are being examined, including bioremediation and monitored natural attenuation. Bioremediation can occur through addition of a carbon source such as acetate or molasses to augment the natural bacterial population which can induce simultaneous reduction and precipitation of uranium in solution. Bioremediation experiments are presently being conducted at U.S. Department of Energy sites in western states. Monitored natural attenuation suggest that ground-water flow that created the deposit moved from an oxidized zone through the orebody to a reduced zone. Re-establishment of ground-water flow after mining should move contaminants from the mined orebody into the reduced zone where natural processes can reduce the contaminants and remove them from the ground water. Questions: 1) Is current ground-water hydrology suitable? 2) What is the reducing capacity of the reduced zone? 3) Do kinetics of reduction reactions in the reducing zone vs. speed of ground water flow? 4) Effects of heterogeneity in mining zone and reducing zone? 5) Can all analytes of concern be attenuated? 6) Monitored attenuation- can the limited time frame preferred by operators be achieved?

Uranium production cycle: Argentine situation

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In Argentina, nuclear power plants at Atucha and Embalse are in operation with very high plant load factors. Atucha II is under construction with the expected start-up in 2012. The long term nuclear power plan of Argentina envisages additional seven units in the next 25 years. It is estimated that the cumulative uranium requirements for these nuclear power plants will be about 30000 tU. However the estimated uranium reserves of Argentina at present in different categories is only approximately 15000 tU.

Sierra Pintada mine, south west of the Mendoza province, was in production from 1975 to 1995 and was kept in stand-by from 1995. Quartz, feldspar, calcite, and kaolinite are the most abundant minerals in the ore. The rock is formed by moderately well-sorted grains of quartz, feldspar, and rock fragments, all cemented by calcite with minor clay replacement.

The mine is an open pit and at 0.025%U cut off about 6500 tU reserves were estimated. Average grade is 0.076% U. The barren – ore rock ratio is 10:1 and barren benches are 10m and ore benches 2.5 m in height. So far 13400000 m³ of barren rock, 376000 t low grade ore and 2500000t plant feed ore has been mined out.

The Sierra Pintada mine is expected to restart operations by 2010. The major problems in restarting this mine are the mining laws, community issues and apprehensions of the local tourism and wine industries. The paper will discuss the mining law in Argentina vis-à-vis the uranium situation and exploration programme for the the next years.

Elaboration of uranium ore concentrate by direct precipitation

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The production of a uranium ore concentrate (yellow cake) is an essential stage in the preparation of fuels used in the nuclear power reactor. In this work, we have studied the elaboration of a uranium ore concentrate from the ore of Tahaggart, testing the direct precipitation process. This choice was justified not only by the physicochemical characteristics of the ore, but also by other important factors such as: capacity of the deposit, its geographical situation (desert), the availability of water and the lowest investment.

Samples of uranium Ore of Tahaggart, were crushed and leached by percolation with a diluted sulphuric acid solution to solubilize uranium. A rate of 95% was reached. The experiments were conducted with sample extracted at different locations in the deposit.

The result obtained showed that the classical direct precipitation process worked only with 5% of the sample. For the majority of sample treated, we noticed a precipitation of uranium at very low pH, only one precipitation step was sufficient to obtain a concentrate of 65% of U_3O_8 . The concentrate obtained is easily soluble in nitric acid. The chemical characteristics of the ore allow us to produce a concentrate using a process simpler than the classical double precipitation process.

The extraction of uranium and thorium from Monazite in Thailand

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Monazite in Thailand, a heavy mineral among others, is associated with tin (cassiterite) deposits. Before the tin crisis in 1985, tin was mined mainly on the southern peninsula, of which 52% was produced from offshore dredging. The heavy minerals were concentrated during the separation of tin and were individually separated using traditional ore dressing techniques. From 1971 to 1989 the total production of monazite in Thailand was 6 400 metric tonnes. Inferred reserves of cassiterite and monazite from offshore are 90 355 metric tonnes and 29 011 metric tonnes, respectively. Production of tin has declined significantly after the tin crisis.

In view of the prospect of the application of nuclear energy in the country, the Thailand Institute of Nuclear Technology (Public Organization) or TINT, considers it important to acquire the know-how of uranium and thorium production, as well as the associated physical and chemical analysis. A bench scale monazite processing plant has been established in Phatumtani province, 50 km from Bangkok, Thailand. Several batches of monazite concentrate, acquired during the period from 1995 – 1997, are used as feed for the process. The uranium concentration of the batches ranges between 0.3 – 0.5% and that of the thorium between 5 – 8%. The concentration of rare earths is approximately 60%, with the concentration of cerium ranging between 25-30%.

Monazite concentrates are opened by hot caustic soda solution. Uranium, thorium and the rare earths are removed from the hydrous metal oxide cake by leaching with hydrochloric acid, followed by the precipitation of uranium and thorium at pH 4.0 and the rare earths at pH 11.0 using sodium hydroxide solution. Uranium is separated from thorium by solvent extraction with 5% TBP in kerosene and thorium is obtained from the remaining aqueous solution by extraction with 40% TBP in kerosene. Studies on the final purification using ion-exchange techniques are under-way. Future plans of the project include studies on the technology of denitration using fluidized bed technologies.

Phosphoric ore treatment by roasting it with sodium carbonate and leaching it with ammonium citrate for the recovery of soluble phosphate and uranium

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By thermal treatment of phosphoric ore, with low phosphorus contents and iron, aluminum, and silicon impurities, basic fertilizers with P_2O_5 soluble in citric acid or ammonium citrate, can be produced. The phosphoric ore lightly grinded with alkaline salts like CO_3Na_2 y SiO_2 is roasted between 800 to 1 000 °C in rotary kilns. The roasted material contains from 25 – 30% of alkaline phosphates soluble in citrates.

Phosphoric ore from the province of Napo-Ecuador with 24% of P_2O_5 , 40% CaO in form of apatite, 20% of SiO_2 and 7 g/Ton U is tested by thermic differential analysis, roasting at 800°C for 2 hours with 50% w/w of sodium carbonate and 2% w/w de SiO_2 by using a Nichols pilot furnace with 15 L of capacity which uses gas (propane-butane) as fuel, and agitated leaching with ammonium citrate (5% w/w). The initial ore and products are characterized by using atomic absorption spectrophotometry (Perkin Elmer AA400) and x-rays diffraction (Bruker D8 Advance). The results of leaching with ammonium citrate are reported.

In the best conditions, 32% of phosphorus soluble in water is obtained as well as 40% of phosphorus and 56% uranium soluble in ammonium citrate.

On-line spectrometric control of technological processes in nuclear fuel cycle

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High sensitive precision gamma spectrometers are required for the various stages of nuclear fuel cycle. Automated HPGe spectrometers for on-line control of the technological processes at the radiochemical facilities are presented.

The automated spectrometer based on conventional coaxial HPGe detector of 10% efficiency is intended for technological monitoring of the radionuclide specific activity in liquid and gaseous flows in the on-line mode. The measuring unit (MU) is a U-shaped glass tube embracing the detector center which is placed in a lead shield. A special algorithm is developed to carry out automated measuring procedure. The spectrometer is able to registrate efficiently the radionuclide specific activity in the total activity range in monitored liquid or gas flow up to 7.3×10^6 Bq/l (2×10^{-5} Ci/l).

The automated spectrometer based on flowing HPGe detector is intended for control of uranium and/or plutonium distribution in fresh fuel elements, as well as for on-line control of the fluids and gases flows with low activity. The cryostat of the detector has the cover of a special design with the through channel which comes via the through channel in the crystal. Coming through the channel in the cover, radioactive sample (fuel element, fluids or gases flow) is found inside the HPGe crystal and the registration geometry comes close to 4π -geometry.

Compare to conventional coaxial geometry the flowing detector registration efficiency is higher for 200 keV -10 times, for 80 keV -20 times and for 40 keV – 70 times. The lower limit of the energy range for the flowing detector was 20 keV compare to 40 keV for the standard detectors.

Presented spectra show that energy resolution and peaks shape in the spectra provide the precision analysis of radionuclide composition in reactor materials and low active flows of the fluids and gases.

What is world's best practice for in situ leach uranium mining?

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Australian Government policy is that uranium mining be approved subjected to world's best practice environmental and safety standards. This paper discusses what this means for in situ leach (ISL) uranium mining in Australia, with particular reference to the Beverley Project in South Australia. It describes technical advice prepared for the Australian Government by Geoscience Australia, drawing on experience from ISL mines around the world. The point is made that there is not a fixed template for world best practice because the characteristics of individual ore bodies determine the best practice for leaching solutions, well-field technology, uranium recovery, liquid waste management and rehabilitation.

Currently, there is a process in train to build on this earlier work to produce formal guidance on best practice ISL in Australia, under a steering group comprising Australian, South Australian, Northern Territory and Western Australian government officials.

Geological characteristics of Indian uranium deposits influencing mining and processing techniques

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Indian nuclear industry is presently nourished by indigenous production of uranium from two ore processing plants (Jaduguda and Turamdih) fed by ore from five underground mines (Jaduguda, Bhatin, Narwapahar, Turamdih and Bagjata) and one opencast mine (Banduhurang) in Jharkhand. Another underground mine (Mohuldih) is also under construction in this area. One large underground mine and processing plant (Tummalapalle) is under construction in Andhra Pradesh. Few more projects are also planned in different parts of the country.

Indian uranium deposits are of medium-tonnage and low-grade occurring in dissimilar geological provinces. In Singhbhum region in Jharkhand, the ore lenses extend as thin veins with moderate dip (~40°) following the lithological contacts. Mine entries like vertical or inclined shafts are planned at the centre of the ore mass preferably in lean zones. Decline entries at new mines are planned after proper assessment of the country rock, inclination of the orebody, joint characteristics, water bearing strata etc. At Banduhurang, low-grade near surface orebody has been developed as an opencast mine after due consideration and optimization of several techno-economic factors. The similarity in ore characteristics (siliceous host rock) in Singhbhum region has helped to adopt identical flowsheet in both Jaduguda and Turamdih plants. However, the difference in work index has necessitated adopting different grinding parameters. Other steps like acid leaching, ion exchange and MDU precipitation etc are common for both the plants.

At Tummalapalle, two parallel ore zones in limestone show consistent dip of 15° for a strike length of 6.6 km. Declines at 9° gradients have been planned along the apparent dip. The advance strike drives are proposed in the strike direction. Because of the carbonate host rock, extensive laboratory and pilot plant studies have been done in finalising the alkaline leaching process. The fine grained nature of minerals within competent host rock has necessitated leaching under controlled pressure conditions. The final product will precipitate as SDU. In sandstone hosted mineralisation at Kyelleng-Pyndengsohiong in Meghalaya, in-situ recovery method was contemplated initially. The relevant geotechnical parameters were found unsuitable following which open pit mining method has been proposed. Due to moderately resistant mineral assemblages, two stages of acid leaching have been proposed in this plant with MDU as the final product. In-pit tailings disposal has been planned which will help in early reclamation of the pit.

At Lambapur-Peddagattu uranium deposit in Andhra Pradesh, the tailings are proposed to be stored in the form of paste (Thickened Tailings Disposal System). At Gogi in Karnataka, fracture controlled mineralisation in limestone and granitic hostrock warrants extensive pre-mining investigations to finalise the mining and process schemes.

The key to successful operation of Indian uranium deposits lies in the extensive investigation of various properties and selection of appropriate technology. Assimilation of global technology with indigenous know-how is the hallmark of the Indian uranium industry.

Recent pilot plant experience on alkaline leaching of low grade uranium ore in India

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Uranium deposits in India are low grade and are relatively smaller in extent as compared to present world wide commercial practice. So far, the vein type deposits of Singhbhum Thrust belt are being exploited for meeting the Indian requirements of uranium. The deposits are currently being processed by acid leaching in the mills located at Jaduguda and Turamdih near Jamshedpur in Jarkhand state of India. The deposits at Jaduguda and Narwapahar are being mined by underground mining and are being processed in Jaduguda mill using air agitated Pachukas. The deposits at Banduhurang and Turamdih are being mined by open cast and underground mining respectively and are being processed at Turamdih by acid leaching in mechanically agitated reactors. The occurrences of uranium in North East and in northern part of Kaddapah basin are relatively moderate in size and are expected to be processed in the near future by acid leaching.

Uranium is also found to occur near Tummallapalle in granitic and lime stone host rocks in southern part of Kaddapah basin [Andhra Pradesh] and in Gogi in Bhima basin [Karnataka]. The deposit in Tummallapalle is relatively lower in grade [$\sim 0.042\%$ U_3O_8] but is a reasonably large reserve whereas that in Gogi is rich in uranium content [$\sim 0.18\%$] but is relatively a small reserve. Laboratory tests based on alkaline leaching have been carried out on both the type of deposits. Studies for Tummallapalle deposits have been extended to pilot plant level and a complete flowsheet has been established with the regeneration and recirculation of lixivants and recovery of sodium sulphate as a byproduct. The process involves alkaline leaching under oxygen pressure in batch type and/or continuous leach reactor using sodium carbonate/bicarbonate as a leaching media and uranium is recovered as sodium diuranate. Based on the techno-economic evaluation of the process, a large scale mill is being set up at Tummallapalle in Andhra Pradesh by Uranium Corporation of India Limited. This paper would present the experimental results of laboratory studies and also the pilot plant experience on alkaline leaching of Tummallapalle deposits.

The experience of using oxidants for ancient roll-front type uranium deposits In Situ Leach mining in the Russian Federation

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Among roll-front type uranium deposits located at the recovery geochemical barrier beyond underground or tabular oxidation zones the most frequently occurring are young ore bodies having an ores' age of ≤ 20 million years. Deposits belonging to this type form massive uranium provinces and regions in Kazakhstan, Uzbekistan, USA, and Australia. Their ancient versions (~135 million years) have been found only in Russia and they form Zursky uranium ore region. Ancient deposits hold 37 000 tonnes in uranium reserves. As opposed to young desposts, ancient ones are characterized by high ore recoverability due to ores secondary post-ore recovery and the presence of diluted hydrogen sulphide in underground waters. If application of artificial oxidants at young deposits may be arguable, the same issue for ancient deposits is expressly resolved in favor of using oxidants. Commercial application of nitrite and hydrogen peroxide as oxidants has demonstrated that such application leads to an increase in uranium concentration in productive solutions and a decrease in sulfur acid consumption during uranium extraction out of ores. The technologies that enable to produce oxidants directly at ISL mines are the most promising.

Environmental
&
Regulatory Issues

Uranium in aquatic sediments: Where are the guidelines?

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Water management at Ranger uranium mine in tropical northern Australia, involves the use of constructed biological wetland filters to passively reduce the concentrations of metals, including uranium and radium, in mine waters before their release off-site. The concentration reduction is achieved principally through partitioning of the metals from the water column into the sediments, resulting in contaminant build-up in the sediments. Environmental Requirements (ERs) for Ranger, enshrined in both Commonwealth and Northern Territory regulations, specify environmental objectives to be achieved during the life of the mine and following closure. While the ERs describe the broad objectives for rehabilitation, specific criteria are required to determine whether these objectives are met; including criteria for the rehabilitation of aquatic sediments contaminated by uptake of uranium and heavy metals.

Routine monitoring of sediments in selected billabongs on and adjoining the Ranger Project Area and strategic environmental research has formed part of the regulatory framework governing the authority to operate for over 20 years. This included studies such as annual routine monitoring of metal concentrations, adsorption-desorption conditions, phase associations, transport mechanisms, release potential, bioaccumulation and bioconcentration etc. Building on this, performance-based monitoring of the sediments from on-site water bodies was undertaken to ascertain the spatial and temporal distribution of contaminants as a basis to determine ecological risks associated with the sediments which in turn underpins closure planning. Highlights of these studies are interpreted using an ecological risk assessment approach.

Ideally interpretation of aquatic sediment contamination in Australia is guided by the national guidelines for water quality (ANZECC & ARMCANZ 2000) and a weighted multiple lines of evidence approach (Simpson *et al.*, 2005) whereby the chemistry of sediments is compared with reference and guideline values and predictions of bio-availability, and biological effects data allows cause and effect relationships to be derived. However, where uranium in aquatic sediments is concerned, there is a lack of national (Australian) and international guidelines that are applicable to tropical sediments and the biological effects data available are limited or confounded by other variables. In the absence of clear uranium guidelines for sediments, an internationally reported “Predicted No Effect Concentration” for uranium in temperate sediments (Sheppard *et al.* 2005), and a value inferred for U from local work (Peck *et al.* 2002), are used as “pseudo-guideline” values to identify sites with concentrations that might present an environmental risk and that should potentially be rehabilitated.

The applicability of these U toxicity values as guideline values for establishing closure criteria is questioned. The difficulty in interpreting the potential bioavailability and biological risks of the uranium in the sediments and the need for international guidelines for uranium in aquatic sediments (tropical and temperate) is discussed, along with plans for future work at Ranger.

The composite interception technology of biochemistry for uranium pollution control at the uranium tailings

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In order to improve the technology for removing the uranium in groundwater, the solubility transformation principle of uranium from hexavalent to tetravalent was analyzed, and the key influenced factors on uranium fixed or separated were studied in this thesis. The composite interception technology of biochemistry (CITB) for uranium pollution control at the uranium tailings was developed. The main research productions were listed as follows.

In the course of zero-valent iron reducing uranium from hexavalent to tetravalent, the acidic condition was benefit for uranium removal. The reaction was first-order, and the ferric oxide could adsorb Uranium (VI). The reaction of Uranium (VI) adsorption by hematite was suit for Ho second-order and Langmuir equation.

The artificial acclimation sulfate reducing bacteria (SRB1) could reduce the soluble hexavalent uranium to the insoluble tetravalent uranium, and the removal efficiency could be up to 98~99%. Uranium(VI), copper(II), cadmium(III), zinc(II), and lead(II) ions could restrain the effect of SRB-1, and copper(II) ion had the biggest effect. When the concentration of NO_3^- was more than 500mg/L or the concentration of SO_4^{2-} was more than 5 000 mg/L, the reduction process was completely restrained. As a result, the mixed sulfate reducing bacteria and de-nitration bacteria were suggested to be used in vitriol and nitric acid mining waste water.

The *Citrobacter sp-* and *Bacillus subtilis* had the characteristics of great adsorption amount, strong endurance, high adsorption velocity and good desorption capacity, and the adsorption efficiency was over 90%, so they could be used for recovering uranium from low concentration wastewater. The *Citrobacter sp-* pretreated by NaOH could improve the adsorption ability. $-\text{COOH}$ and $-\text{NH}_2$ had important effect on adsorption, and the dead bacteria cells could adsorb more uranium than the living cells. When *Bacillus subtilis* was fixed by 4%PVA+1% sodium algal, the effect was better.

According to integrated utilize the biological adsorption and recovery technology, chemical reducing technology and biological conversion technology, the composite interception technology of biochemistry for uranium pollution control at the uranium tailings was put forward. This technology could ensure the concentration of uranium in mining waste water meet the national standard, and it was successfully used in both bench-scale and pilot-scale experiment. The removal efficiency was more than 99%

Uranium ISR mine closure – general concepts and model-based simulation of natural attenuation for South-Australian mine sites

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Heathgate operates the Beverley uranium mine and is currently developing the nearby Beverley Four Mile project on behalf of a Quasar Resources – Alliance Resources joint venture. Both sites are located on the arid plane between the Flinders Ranges and Lake Frome, approximately 550 km North of Adelaide in South Australia. In-situ recovery (ISR) technology has been thoroughly adapted to the local conditions and is applied in a moderately acidic milieu, mobilizing uranium in the mineralized aquifers by oxidation with hydrogen peroxide mainly. In particular, the optimization of ISR technology under the local constraints resulted in a stringent minimization of waste water volumes from U processing (discharged to abandoned wellfields in isolated ‘bathtub’ aquifers) without producing radioactive solid waste. Natural attenuation (NA) is acknowledged as an appropriate control measure for ISR mines to avoid impacts on the aquifer environment surrounding the ISR wellfields. Data from the Beverley operation in a series of confined, nearly stagnant aquifers indicate that NA has considerably reduced the impact of ISR on groundwater and that a return approaching pre-mining conditions can be expected to occur in time. In order to demonstrate the effect of NA in post-mining scenarios for the new operation a comprehensive work program including:

- Groundwater flow modelling
- Geochemical laboratory test work
- Geochemical modelling (reactive transport) and
- Ongoing, iterative NA modelling validation and assessment

has been established, also considering comprehensive mineralogical data from core investigations. In both the Beverley and the Beverley Four Mile deposits, uranium is found as coffinite in fine to coarse grained quartzose sands, whereas both ISR chemistry *and* NA are mainly defined by the most reactive minerals pyrite (reducing), calcite (neutralizing), kaolinite (neutralizing) as well as other silt/clay minerals with some ion-exchange capacities. A reactive transport model (TRN) combines transport (advection and dispersion) with geochemistry (kinetics and thermodynamics). The experimental results of both batch tests and dynamical column tests performed with core samples and mining fluids in each case were *consistently* reproduced in the model framework which has been reliably calibrated for the present application in this way. The upscaled model was applied to realistic post-mining scenarios at Beverley Four Mile, thus demonstrating the immobilization of dissolved uranium and the effect of NA on groundwater restoration (return to chemically neutral and reducing conditions). The TRN approach refines a recent U.S.G.S. study of groundwater restoration after in-situ leach mining (based on PhreeqC) by introducing a well-calibrated model in a more realistic model space and run at higher resolution. The paper will demonstrate predictions for several cases and discuss results in view of the mine-closure concept of monitored natural attenuation (MNA). The present NA study has been presented in the application documents for the Beverley Four Mile Project.

An overview of the international transport of uranium concentrates

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Uranium ore concentrates are transported internationally by road, rail and sea from the uranium producers to uranium converters. The concentrates are LSA-1 type material transported in IP1 packaging, typically standard open-head steel drums. Transport generally involves the use of dry 20' sea (ISO) containers. International routes involve sea transport and often include both rail and road segments. The combination of multiple transport modes can result in more demanding conditions of transport.

As greater attention is given by national and modal authorities to the handling of cargo classified as dangerous goods, shippers are re-evaluating their methodology for transporting such cargoes. As well as being classified as dangerous goods (Class 7), there are additional requirements and areas of regulatory interest applicable to uranium concentrates.

The World Nuclear Transport Institute (WNTI) is an international industrial organisation which represents the collective interests of the radioactive materials transport sector and also those who rely on safe, effective and reliable transport. Over the past few years, WNTI has grown dramatically with member companies drawn from a wide range of industry sectors, including major utilities, fuel producers and fabricators, transport companies, package producers, etc. A major initiative was launched within the WNTI with the setting up of a Task Force to discuss and explore issues relating to uranium concentrates transport. The principal objective was to explore the three main aspects of uranium concentrate shipping in ISO containers: (i) the drums used for packaging; (ii) the containers themselves; and (iii) restraint of the drums in the containers.

A WNTI Information Paper identifying examples of good practice for multi-modal shipping of uranium concentrates in ISO containers has been developed by the Task Force. This document provides a basis for a more harmonized approach to uranium concentrates transport.

Environmental remediation and radioactivity monitoring of uranium mining legacy in Portugal

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Uranium mining is an old extractive industry, although during the first half of the 20th century this industry has been mainly operated in the behalf of radium production (²²⁶Ra). The first uranium ore mining took place in Europe, leaving a legacy of mining and milling sites not immediately rehabilitated and mostly without environmental remediation plans and provision of funds for it.

In the last decades developments of uranium mining displaced the core of uranium mining activity from Europe to other regions. In the coming years, uranium mining is expected to grow further due to the possible increase in nuclear power production. Meanwhile, most of former uranium producers in Europe enforced legislation that requires site management to comply with new radiation dose limits of 1 mSv/y to members of the public.

Compliance with these new radiation dose limits is the main goal for the environmental remediation programs implemented in European Union countries, including Portugal, aiming at ensuring sufficient radiation protection to humans and to the environment. Progress in environmental remediation of former uranium mining and milling sites in Portugal is presented, namely at the former milling tailings area of Urgeiriça. The environmental radiological surveillance program implemented around former mining and milling sites is presented also with an account of environmental radioactivity levels in the region.

From the uranium mining legacy, the lessons to learn include the need for forward planning of radiation protection measures for the complete mine life cycle in order to minimize the exposure of the public to ionizing radiation and to toxic metals, and to reduce the environmental impact and environmental remediation costs. Today this is an essential societal requirement, and public trust for future uranium mining is probably also built on the success of remediation of uranium mining legacy sites.

The regulatory perspective on radiation protection in Canadian uranium mines

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The Canadian Nuclear Safety Commission (CNSC) is the principal nuclear regulator in Canada. The CNSC is empowered through the Nuclear Safety and Control Act (NSCA) and associated regulations, to regulate the entire nuclear cycle which includes: uranium mining and milling, uranium refining and processing, fuel fabrication, power generation and nuclear waste management. Radiation Protection is one of the main safety and control areas mandated under the NSCA and its regulations which specify certain regulatory controls and limits. These Radiation Protection measures are required to manage the risk to the public, the workers and the environment and are considered in all our licensed activities at uranium mines and mills. The CNSC expects its licensees to demonstrate a healthy respect for radiation protection and look for this behaviour in the managed systems. Confirmation that this has been adopted as part of the licensee's safety culture is obtained through our inspection activities. This paper will describe the regulatory controls and explain how they are applied by using an underground uranium mine, a uranium mill and a uranium tailings management area.

Regulatory oversight of uranium mines and mills

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The Canadian Nuclear Safety Commission (CNSC) is the principal nuclear regulator in Canada. The CNSC is empowered through the Nuclear Safety and Control Act (NSCA) and associated regulations, to regulate the entire nuclear cycle which includes uranium mining and milling. The paper discusses the regulatory oversight of uranium mines and mills which include:

- Who is CNSC, what is the CNSC's mission and CNSC background
- Oversight Management System
- Regulatory Framework
- Expectations for Assessing Compliance
- QA Principles and Program Elements
- A Look to the Future
- Planning regulatory oversight activities
- Management System Documentation Review
- Regulatory Oversight Activities
- Following-up On Inspections
- Enforcing Compliance with Requirements
- Improving the Regulatory Oversight Process

Uranium Mining in Paraguay: An opportunity to improve the environmental regulations in mining

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In many respects uranium mining is much the same as any other mining activity. In Paraguay under the Environmental Law, as well as many other South American countries, projects must have environmental permits prior to commencing, and must comply with all environmental, safety and occupational health conditions applicable. Increasingly, these activities are regulated by international standards, with external audits. The capacity for enforcement varies from the experience and tradition in mining production. Mining in Paraguay is a very recent activity; and as well as the Environmental Authority was recently created in 2000; therefore the environmental legislation for mining is not developed. Once the mining activity is approved, open pits or shafts and drives are dug, waste rock and overburden is placed in engineered dumps. Tailings from the ore processing must be placed in engineered dams or underground. Finally the whole site must be rehabilitated at the end of the project. Meanwhile air and water pollution must be avoided. The nuclear Renaissance in the world is a result of the high prices of oil and governments commitments on reducing the Greenhouse Effect Emissions under the Kyoto protocol: many governments expressed their willingness to increment their uranium predictions as well as the nuclear energy generation. Representatives of the Paraguayan Government after a meeting of the National council of Defense had stated that the issue of uranium exploration and has a strategic significance, and it has requested the preparation of environmental regulations to regulate this activity. The sector development strategy has also been discussed within the National Council of Defense. In this regard upon request of the National Environmental Authority and with support from USAID cooperation a process of preparing regulations for uranium mining has initiated by considering the cases of remediation and liabilities left by uranium mining in Australia - Nabarlek; Gabon-Mounana; Australia - Valle South Alligator; Kyrgyzstan and Kazakhstan. Once the uranium mining process and risks were evaluated by the authorities, and taking into considerations that the process is common to all metalliferous mining, and are well recognized and understood, the government decided to prepare an Environmental Regulation for General Mining. Also a particular regulation for uranium mining was prepared and was included in the Standards Protocols and Term of References for Uranium Mining. The proposed regulation states the follow stages of the process: mine site rehabilitation assessment, environmental risk assessment to determine what environmental assets are at greatest risk from multiple threats, assessment of the biophysical impact of mining on people; assessment of the impact of uranium mining and chemical and biological control regimes to ensure that the aquatic and terrestrial ecosystems are protected from the operation of mines in the region. Finally in the Environmental Management Plan an environmental monitoring is implemented for early detection of effects in the environment, arising from dispersion of mine waters during the rain and wet season. It is expected that with the proposed environmental regulation, uranium mining will be encourage in Paraguay.

Issues in developing a new uranium mine in Canada

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The resurgence of interest in nuclear power as reflected in the interest in new nuclear reactors in Canada and world-wide, has spurred demand for additional uranium supply. The expansion of the search for new uranium resources has resulted in a major increase in public opposition to uranium resource development. Energetic anti-uranium mining groups have arisen around the world but are particularly noticeable in Canada, United States and Australia – three countries with a significant uranium mining history and proven, economic uranium resources. In Canada, exploration activities are regulated by the provinces and territories. All aspects of developing a mine through to decommissioning are regulated federally by Canadian Nuclear Safety Commission and subject to a federal environmental assessment (EA). Such assessments are comprehensive in nature and require evaluation of all aspects of the development from construction to closure. An integral component of an EA is public consultation. Concerns of people who would live near new mines or mills are enhanced by comments from local, national and international NGO's, and the risks from mining are often overstated and indeed, misrepresented. Countering these concerns is frequently a challenge, particularly since experts who can be considered independent and are able discuss evidence of very low risks, i.e. are not associated with a mine development, are unlikely to get involved in public discussions.

In several Canadian jurisdictions, new developments have been blocked or post-poned as the result of local concerns, especially from aboriginal people who may express specific concerns related to traditional life styles. The concerns are typically focused on two key areas: *will the radiation associated with the mining harm my family* and *will the mine wastes harm the environment now or in the future?* Expressed in another way, members of local communities often want the economic benefits of a mine but are concerned whether a family member, children of mine workers or future generations would be harmed by the radiation. In some ways, uranium tailings and waste rock are unique mine wastes. Typically the tailings have been subject to chemical leaching and leach residues include some soluble materials and residues that host residual radionuclides which are principally the uranium -238 series daughters minus most of the uranium. Many of the negative impressions that people have today of uranium mines originate from reported historical practice and concerns over radioactivity escaping into the environment and harming plants, animals and people. It is this concern over radioactivity that fosters public concern that is frequently exaggerated, but earnestly believed. The result is that tailings, waste rock and treatment sludges are managed in a way that provides absolutely minimal risk to local people and to the environment. At some high grade Canadian mines highly engineered pit disposal of tailings and waste rock offers the additional advantages of minimal long term management and returning the land to unrestricted use. The level of diligence varies globally but is recently trending to very conservative management strategies in all countries. A challenge for the development of future deposits, especially those with lower grades and larger volumes of tailings, will be how to achieve the high level of safety expected for tailings management at an affordable cost.

Uranium mining and milling environmental liabilities management in Germany: Lessons learned during almost two decades of implementation of the Wismut Rehabilitation Project

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From 1946 to 1990 the Soviet-German WISMUT Company produced 231 000 tonnes of Uranium and became with it the world's third largest uranium producer at that time. Due to the mining of low grade ore, about 800 Million tonnes of waste rock material, radioactive sludge's and overburden material were deposited at the sites. The mining and milling activities resulted in seriously affected and devastated areas in a densely populated region of about 10 000 km² in Saxony and Thuringia, in East Germany. In 1990 after the German re-unification the uranium production was ceased and the German government was faced with one of its largest ecological and economic challenges because WISMUT turned at once from the production to the decommissioning phase without any preparation or preplanning. Since 1991 the national corporation WISMUT GmbH has been charged with the decommissioning of the mines, mills and other facilities and with the rehabilitation of the sites. The overall project includes abandonment and flooding of underground mines, relocation and covering of waste rock piles, dewatering and geo-chemical stabilisation tailings management facilities, demolition of structures and buildings, site clearance and rehabilitation. The WISMUT Rehabilitation Project is in an advanced stage. More than 93% of the mine workings are flooded, flooding has been accompanied by operation of powerful water treatment plants. Roughly 90% of technical structures have been demolished, relocation of 131 Million tonnes of waste rock and overburden material into the Lichtenberg open pit is terminated, and more than 60% of the rock piles and tailings management facilities have been covered. The advanced stage gives rise to draw first conclusions on the outcome of the rehabilitation activities. The present paper presents the main results of the WISMUT Rehabilitation Project and summarizes lessons learned by now.

Screening assessment of radionuclide migration in groundwater from the “Dneprovskoe” tailings impoundment (Dneprodzerzhynsk City) and evaluation of remedial options

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The paper presents results of mathematical modeling of the hydrogeological conditions at the “Dneprovskoe” (“D”) tailings impoundment –object of the former industrial association of “Pridneprovsky Chemical Plant”, which contains uranium ore processing wastes. This radioactively polluted site is located in a densely populated region (at the outskirts of Dneprodzerzhynsk City) near the major watercourse of the Ukraine – Dnieper River.

The mathematical modeling utilized Visual Modflow (for groundwater flow) and Ecolego (Facilia AB, Sweden) radioecology modeling software (for radionuclide transport).

Modeling results indicate the possibility of essential radioactive contamination in future of the phreatic aquifer in alluvial deposits between the “D” tailings and the Dnieper River (mainly due to migration of uranium). Therefore long term management strategies should preclude water usage from the aquifer in the zone of the influence of the “D” tailings. Filtration discharge of uranium to the Dnieper River does not represent a significant risk due to large dilution by surface waters.

The important modeling conclusion is that besides the uranium ore processing wastes inside the tailings, the major source of radionuclide migration to groundwater is represented by contaminated geological deposits below the tailings. This last source was formed due to leakage of wastewaters during the operational period of the “D” tailings (1954-1968). Therefore an exemption and re-disposal of wastes from the “D” tailings to a more safe storage location (proposed by some remedial plans) will not provide significant benefit from the viewpoint of minimizing of radionuclide transport to the groundwater and Dnieper River (especially in short-and medium-term perspective).

The rational remedial strategy for the “D” tailings is conservation of tailing wastes *in-situ* by means of specially designed “zero flux” soil screen, which would minimize infiltration of meteoric waters to the body of the “D” tailings (and would respectively minimize groundwater contamination).

The Namibian Uranium Mining Model: Voluntary sector initiatives underpinned by a regulatory safety net ensures best practice

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As a developing country, Namibia is facing the challenges of poverty, unemployment, a growing demand for energy, a life expectancy that has decreased from 65 years at Independence to 50 years now, and about 100 000 orphans that need education, health and housing. It is heavily reliant on capital intensive natural resource extraction such as uranium mining and although the worldwide recession is relentlessly affecting all economies the demand for uranium appears to be least affected. Namibia has extensive deposits of low-grade uranium and is regarded as a region of global importance for this source of energy. Namibia has a long history of uranium mining, dating back to 1976, when Rio Tinto's Rössing uranium mine opened. After 30 years of production and imminent closure, Rössing is responding to the recent increase in demand for uranium by launching an expansion programme. Paladin Energy's Langer Heinrich Uranium project came online in early 2007 and these mines account for about 9 % of the world's uranium and are set to maintain their current production. Two more projects are expected to come on stream. This includes, Areva's Trekkopje, in 2009, followed by Valencia in 2010. If the baseline feasibility and environmental impacts studies are accepted, three other mines, Swakopmund Uranium, Bannerman and Reptile Uranium show potential and may come on line in 2014. Other projects are currently in exploration stages and analysts expect that uranium exploration and mining activities could have a significant impact on the Namibian economy during the next few years. In Southern African countries, legislative frameworks are generally broad and fragmented and are not conducive to sustainable development. Voluntary product stewardship schemes have arisen out of the need for the industry to balance their pursuit of economic gain with environmental and social concerns and by doing so, demonstrate their contribution to sustainable development even in a climate of weak regulation. In response to the country's growing uranium industry Rössing Uranium Limited as the pioneer and flagship of the Namibian uranium mining industry (and a founding member of the Chamber of Mines of Namibia), together with the new Langer Heinrich Uranium Mine, championed the need for the Chamber to develop minimum standards for occupational health and environmental management for uranium exploration and mining activities in Namibia. It was obvious that there is a need for a Uranium Stewardship committee that can collectively address the issues of stewardship, sustainability and good governance. In 2007, The Chamber established an office in Swakopmund and appointed a Consultant to spearhead the process, in consultation with local stakeholders, the International Atomic Energy Agency (IAEA) as well as the World Nuclear Association (WNA). The initiative is jointly funded by Rössing Uranium Limited and Langer Heinrich Uranium and the explorations companies assisted financially with the establishment of an independent Strategic Environmental Assessment (SEA) study. The Namibian Government has taken important steps in responding to the dearth of inadequate legislation with the promulgation of The Minerals (Prospecting & Mining) Act, No 33 of 1992, the Minerals Policy (2005), Atomic Energy and Radiation Protection Act, 5 of 2005 and the Environmental Management Act, 7 of 2007. The Namibian approach is an example of voluntary sector initiatives underpinned by a regulatory safety net to ensure environmental and social sustainability and internationally accepted health standards across the board.

WNA's worldwide overview on front-end nuclear fuel cycle growth and health, safety and environmental issues

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This paper presents the WNA's worldwide nuclear industry overview on the anticipated growth of the front-end nuclear fuel cycle from uranium mining to conversion and enrichment, and on the related key health, safety and environmental issues (or key HSE issues) and challenges. This paper subsequently puts an emphasis on uranium mining in new producing countries with insufficiently developed regulatory regimes that pose greater HSE concerns. It describes the new WNA policy on uranium mining: Sustaining Global Best Practices in Uranium Mining and Processing – Principles for Managing Radiation, Health and Safety and the Environment, which is an outgrowth of an IAEA cooperation project that closely involved industry and governmental experts in uranium mining from around the world. Given the expansion of nuclear power, world uranium production must grow quickly to meet increasing demand. Production in the major uranium producing countries, such as Canada and Australia, will be expanded, but the most key increases are likely to come from Kazakhstan. In situ leaching (ISL) is expected to represent a greater share of uranium production. Conventional mining is expected to remain dominant. Uranium production is also likely to start in some new countries, mainly in Africa. Conversion facilities will be expanded to cope with rising demand. The most significant feature in enrichment will be the gradual replacement of the older gas diffusion facilities (France and United States) by heavy investment in gas centrifuge facilities. Elsewhere, both Western Europe and Russia will likely expand their existing centrifuge capacities. Investors in the SILEX laser enrichment technology will try to commercialise it within the next five years. No key HSE issues are foreseen for the global expansion of conversion and enrichment. The upgrade of existing plants and new plants are expected to deliver greater HSE performance. One of the most notable improvements arises from the much lower energy consumption of centrifugation enrichment plants. Concerning uranium mining, current HSE performance is expected to continue improving in uranium producing countries which benefit from well established regulatory regimes. The real HSE challenges rather point at new uranium producing countries with insufficiently developed regulatory regimes. Recognizing this, the worldwide community of uranium mining and processing has issued the above stated new WNA policy. Above all, the biggest broad challenge is about fully considering nuclear energy (and the front-end nuclear sector) as an integral part of the world challenge on growing energy needs and on growing climate change and environment-health issues. A 2nd broad challenge is to further convey the integrated management of HSE issues through a harmonized common set of revised IAEA safety standards. A 3rd broad challenge is the fact that radiological protection (RP) policies must be further improved at very low doses. Experience has repeatedly shown that a loose application of the assumed down-to-zero risk model (LNT) leads to imbalanced RP policies for the public. A 4th broad challenge is to reposition well recognized and improved safe nuclear technologies as one of the main drivers for the deployment of nuclear energy and nuclear fuel cycle projects. The ever more stringent new standards and practices which have been ill-imposed on nuclear projects (e.g. because of perception issues that go far beyond the notion of protection) must be dissociated from the drive to deploy nuclear projects. Instead, the tiny HSE impacts from such projects should have a minor role.

Legal aspects related to the decommissioning, operation and implementation phases of the uranium mines belonging to the Indústrias Nucleares do Brasil - INB

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The Indústrias Nucleares do Brasil – INB is company with both private and public capital, linked to Comissão Nacional de Energia Nuclear – (CNEN) and to the Brazilian Ministry of Science and Technology. It has facilities in the states of Bahia, Ceará and Minas Gerais, with corresponding uranium mining and milling plants, which represent the first stage of the Nuclear Fuel Cycle. Caldas Unit (decommissioning phase) – First mineral-industrial complex settled in the country, located in the municipality of Caldas, at the southern State of Minas Gerais, since 1982. Here the development of the nuclear fuel cycle technology was started aiming at generating electric power, through uranium processing by chemical treatment and its transformation into yellowcake. Due to the exhaustion of the economically feasible uranium, the facility stopped its production in 1996, and the priority was to transfer the mining activities to Caetité (BA) in the late nineties. Caetité Unit (operational phase) – One of the most important Brazilian uranium ore provinces, is located in the southwest of the state of Bahia, near the towns of Caetité and Lagoa Real. The mining of uranium ore, with average content of 2 900 ppm in U_3O_8 equivalent, is underway since 1999 in an open pit mine at the Cachoeira deposit. Milling takes place at the industrial facilities for the extraction of uranium through acid heap leaching in piles, and concentration and purification through solvent extraction in countercurrent method, followed by the production of the corresponding concentrate as ammonium diuranate – ADU, or yellow cake. The current yearly production of ADU reaches 400 metric tonnes in U_3O_8 equivalent. The next step, presently being licensed, will be a shift on the mining process, from open pit to underground mining, aiming at a more economical exploration of the ore. It will be the first underground uranium mine in our country. Santa Quitéria Unit (implementation phase) – The Santa Quitéria deposit is located in the center of the state of Ceará, about 45km southeast from the municipality of Santa Quitéria. The Santa Quitéria deposit is characterized by the presence of uranium associated to phosphate and, although being the largest uranium reserve in the country, its economical feasibility depends on the exploration of the associated phosphate. This means that the uranium extraction is conditioned to the production of phosphoric acid – an input used to produce fertilizers. This fact makes its licensing process rather unique. The status-quo of all INB's present undertakings – decommissioning, operation, implementation – presents unusual characteristics in our country, both in its regulatory and region-oriented environmental aspects. Carrying out with these different processes requires a lot of study, by both operators and regulators. Operators are seeking the necessary knowledge to comply with the regulators' demands, by means of contracting consultants, exchanging information with foreign institutions, with experience on the subjects involved, and by investing in the training of its own personnel. The groundbreaking character of such ventures also leads to the need of the entrepreneur to launch social and environmental guidelines, as well as definition of programs to keep the communities involved and stakeholders well informed of their action. The focus of this paper is to discuss the present situation of the above mentioned undertakings, their groundbreaking characteristics in the country and the operator's difficulties in treating the aspects related to the legal, environmental, social-economical and security issues.

Environmental impacts and issues of In-Situ leach uranium mining in the United States of America

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In-situ leach (ISL) mining of sandstone-hosted deposits has been steadily producing uranium in the U.S. since the late 1970s. In Texas, 38 mines have extracted uranium along the southwest Texas coastal plain. Wyoming production has come from three mines developed in the Powder River Basin, and Nebraska has one active ISL facility in the Crawford Basin. Twenty new or expanded ISL mines are expected to submit license applications within the next two years. Increasing concern over groundwater degradation resulting from uranium ISL mining has resulted in more extensive state regulation and prompted the U.S. Geological Survey to review restoration data for these mines to quantify environmental impacts and critical issues.

ISL mines in the United States inject oxygen or hydrogen peroxide enriched ground water into reduced roll-front deposits to extract uranium via carbonate-uranyl complexes in ground water. Some operators add carbon dioxide, carbonate or bicarbonate to the lixiviant as a carrying agent, although sandstones in the U.S. commonly contain enough native carbonate that this is unnecessary. Other lixiviants utilized in past operations including sodium and ammonium bicarbonate and sulphuric acid are not used in modern U.S. operations because of difficulties in restoring ground water to pre-mining conditions.

Baseline studies show Ra, U, As, Pb, Cd, Se, and Hg in groundwater before ISL mining are typically elevated above U.S. Environmental Protection Agency (EPA) drinking water Maximum Contaminant Levels (MCL). Cl, Mn, Fe, total dissolved solids, and sulfate are commonly elevated above secondary EPA standards. Newly-raised challenges to ISL mining have questioned the validity of statistical methods used when calculating baseline values in ISL operations.

Restoration techniques used in U.S. ISL well fields are dominated by ground water sweep and treatment of ground water by reverse osmosis. Additionally, two well fields have been restored using bioremediation. In other well fields reductants (hydrogen sulfide gas and sodium sulfide) have been used to reverse the effects of oxidizing lixiviants. Ra, U, As, Pb, Se, Cd and Hg are sometimes elevated above MCL after restoration as are Mn, Fe, Cl, total dissolved solids and sulfate. Criticism about inadequate monitoring has led to proposed regulation changes lengthening post-restoration monitoring.

None of the restoration techniques identified to date have been successful in returning all ground water parameters to baseline. However, some well fields have been restored to "class of use" which generally satisfies state requirements.

Licensing process of a uranium ore mining and milling facilities located in the State of Bahia, Brazil

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The Uranium Concentrate Unit – URA – is a plant consigned to uranium ore research, mining and milling activities. The plant aims at producing natural uranium concentrate, in form of ammonium diuranate – ADU, used as raw material for fuel production for nuclear plants. The plant complex is established in an area belonging to Caetité, a town located at the southwest of the state of Bahia, Brazil. The uranium ore mining, with average content of 2,900 ppm of U_3O_8 equivalent is done in an open pit mine, at the Cachoeira Deposit. Milling takes place in the industrial facilities built for the extraction of uranium through acid pile leaching, concentration and purification through solvent extraction in countercurrent method, and the production of the corresponding concentrate, in form of ammonium diuranate (ADU). The yearly production of ADU reaches 400 metric tons of U_3O_8 equivalent.

It should be pointed out that URA shall evolve, in a future extension program, into other mining and milling projects to produce uranium concentrate, keeping exploration through underground mining in the area now in operation and extending the work to other areas comprising the uranium province of Lagoa Real. Every nuclear facility to operate in Brazil needs a license from its environmental agency – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA, and from the regulatory agency that controls the nuclear activities in the country: Comissão Nacional de Energia Nuclear – CNEN. The licensing process comprises well defined steps that must be fulfilled, otherwise licenses become invalid. The analysis of documentation produced along the process, help to evaluate occasional impacts of the activities being licensed. Only after fulfillment of all steps, licenses and authorizations are issued to release the operation of the facility. Conditions and requirements are imposed on the entrepreneur/operator whenever necessary, in order to reduce negative impacts thereof to guarantee safe operation.

The process established by CNEN for activities related to siting, construction and operation of nuclear installations, involves Site approval; License for Construction (total or partial); Authorization for the Use of Nuclear Material; Authorization for Initial Operation; and Authorization for Permanent Operation. The environment licensing procedure, in charge of IBAMA, includes the granting Previous License (PL); Installation License (IL); and Operation License (OL). The URA licensing process was started in October 1997, through the obtainment of IBAMA's Previous License and Site Approval, by CNEN. At present, URA has the Operation License n° 274/2002 (valid for 6 years) and the Authorization for Initial Operation, issued by CNEN on 09.04.2007.

This paper discusses the aspects related to nuclear installation licensing, featuring all steps of the process, emphasizing the operator's difficulties and the demands of control agencies toward completion of related information. It also approaches the epidemiological study, required by IBAMA, during the process of environment licensing, in order to define possible influences of URA's activities on the neighboring population health.

Radiation safety and environmental protection issues of uranium mines and mills in Brazil

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In 1971 an immense uranium ore deposit was discovered in Caetité, Bahia, at the Northeast region of Brazil, estimated to have about 100 thousands tonnes of uranium concentrate (U_3O_8). Up to 1995, Brazilian needs were restricted to feed the nuclear reactor Angra 1, then supplied by the first Brazilian mine located in Caldas, Minas Gerais. When the Government decided to finish the next reactor, Angra 2, it became necessary to have larger supplies of uranium concentrate. Therefore, the project of producing uranium in Bahia was elaborated by the Indústrias Nucleares do Brasil - INB, complying with all the strict national and international safety and environmental protection regulations. Considering the mineral characteristics and the very dry weather conditions of the region, it was decided to use the heap leaching process to extract the uranium ore. After being crushed, the ore is piled and irrigated with a sulphuric acid solution. This technique spares the milling, mechanic agitation and filtration phases, allowing, besides a substantial investment reduction and operation at smaller costs. The extraction process accomplishes the uranium concentration by organic solvents, followed by separation by precipitation, and drying. One of the characteristics of the process is that it can be carried out without the need for liberation of effluents to the environment. Recently, the Brazilian Government announced the decision to resume the construction of Angra 3, and there are plans for the construction of four other new nuclear plants. Accordingly, projects for the expansion of the current uranium production capacity in Caetité were developed, and comprise going for underground mining and shifting to conventional leaching.

This paper summarizes the present status of radiation safety and environmental protection activities that are in place in and around the uranium mine and milling facilities of Caetité. It describes the workforce radiation protection measures, including dose assessment for direct exposition and incorporation, over the years of operation, and measures envisaged to comply with the future expansion of the enterprise. The environmental protection programme is presented, detailing the continuous monitoring of up to 30-kilometer area around the unit, including the control of: underground and rain water, air, soil, grass, agricultural products and milk. Reference is made to the request made by INB for hosting the IAEA Uranium Production Site Appraisal Team (UPSAT) programme mission, in order to provide assessment of the status of present operational safety and operational practices for both mining and milling at Caetité.

Radiological safety in mining of low grade uranium ores: Four decades of monitoring and control in Indian mines

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Mining of low grade uranium ore involves deployment of large man power in many stopes simultaneously to achieve the production target. The first uranium mine in India commenced commercial operation in 1968 with production from shallower haulage levels. The mine is now operating up to a vertical depth of about 905 meters. Radiation exposure of workers is mainly from external gamma radiation and inhalation of radon progeny. The long lived alpha emitters in the airborne ore dust are relatively small in such mines. While gamma radiation is not amenable to control the radon and its progeny can be effectively reduced by adequate ventilation and a judicious distribution of ventilating air to the working zones and sealing of worked out areas. Workplace monitoring for radiological parameters in the mines commenced right from the beginning of the operations. Initially the effective dose to the workers was evaluated from the area monitoring and occupancy period of workers in different zones. Subsequently, SSNTD and TLD based personal dosimeters were developed and deployed in a phased manner. Average dose to the workers in the early stages was around 10 mSv/y. Ventilation was progressively improved by widening of air passages and increasing the fan capacity. The system itself was modified from the series to a parallel system of ventilation to supply fresh air to each operating haulage level and allow the used air to join the return air stream. The modifications had positive impact and the average doses have shown a downward trend are now around 5 mSv/y. Progressive mechanization of mining operations over the years has resulted in reduction of manpower and consequently in a reduction of the collective dose. Subsequently, three additional underground uranium mines have been opened with low grade uranium ores. Increasing ventilation has resulted in reduction of radon concentration to an average of around 0.3 KBq/m³ EER in Jaduguda mine. The internal and external radiation dose fractions for this mine has been around 0.45 and 0.55, respectively, in recent years with some variations for the different mines. The paper gives an overview of the monitoring for external radiation, radon and the long-lived alpha emitters in the mines. The trend of doses in Jaduguda mines is given for the last four decades and recent data for the other mines are summarised. Efforts made to increase the ventilation and its impact on radon control is also discussed.

Temporal changes of radioactive contamination of Ploučnice River Inundation Area

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The inundation area of Ploučnice river has been contaminated by natural radionuclides during the early mining of the uranium ore deposit in the region of Stráž pod Ralskem, Northern Bohemia, i.e. in the seventies and in the eighties of the last century. The evaluation of the level of contamination is connected with many problems. During several floods that occurred after the primary contamination, the contaminants were spread to a relatively large territory, but the level of contamination is very variable. Large regions have not been affected at all, and measured values of gamma dose rate are comparable with the values of natural background. On the other hand, a higher contamination can be found at small areas, often situated far from the river - for example in catchwater drains. Moreover, many contaminated areas are located in places that are difficult to reach. The topographical orientation is also complicated in such places.

A study of temporal changes of contamination was based on a comparison of data obtained using two different methods: airborne gamma-ray spectrometry and detailed field gamma dose rate measurements.

Airborn gamma-ray spectrometric data from 1991 - 1993 and from 2005 (measured using the same instrumentation) were available for the study. In both cases, the airborne survey was realized with the 256-channel gamma-ray spectrometer GR 820 D. Basic parallel flyways distanced 250 m at the height of flight of about 100 m above the Earth's surface were used to cover the whole territory.

As for the results of detailed field gamma dose rate measurements, several measurement campaigns have been organized during previous 20 years. But only a part of available data is applicable to the analysis of temporal changes of contamination, because different approaches and different measuring techniques were used in the campaigns. To get an information on the present situation in several chosen „hot spots“, a detailed field survey was performed in 2008. The gamma dose rate on the ground surface and at the height of 1 m above the ground was determined with the field gamma-ray spectrometer Gamma Surveyor and with the radiometer DC-3E-98.

The analysis of data indicates a decrease of contamination with time in a majority of contaminated areas. Advantages and disadvantages of both approaches to the evaluation of the level of contamination (airborne gamma-ray spectrometry, field gamma dose rate measurements) are described.

The radiation protection programme at the Nuclear Materials Authority of Egypt

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The development of environmental and safety regulation programme at the Nuclear Materials Authority (NMA) of Egypt is described and the impacts of these developments on various phases of the uranium mining and milling are illustrated. Also, the monitoring and dose assessment for the individual and workplace at the mining operations and laboratories were explained. Meanwhile, a radiation protection programme (RPP) may relate to all phases of a practice or to the lifetime of a facility from design through process control to decommissioning. Therefore, the RPP covers the main elements contributing to protection and safety, and is a key factor for the development of a safety culture. The general objective of RPPs is to reflect the application of management responsibility for protection and safety through the adoption of management structures, policies, procedures and organizational arrangements that are commensurate with the nature and extent of risks. Therefore, the RPP may include protection of workers, the public and the environment. Also, implementation of the optimization principle should be the principal driving force to prevent or reduce potential exposures and to mitigate the consequences of accidents. Therefore, upgrade emergency plan should be ready and active beside written procedures should be used as apart of the work planning process as appropriate. Meanwhile, the education and upgrade training programme introduce in regular intervals, annually, which include an information and recommendation of the international relevant organizations and the basic principles of radiation protection against ionizing radiation. The design and implementation of a monitoring programme should conform to quality assurance and quality control requirements, to ensure that procedures are established and followed correctly, and that records are promptly made and correctly maintained. So, the equipment to be used in the monitoring programme should be suitable for the radiation type(s) and the form(s) of radioactive material encountered in the workplace. Also, the equipment should be calibrated to meet appropriate standards. The Radiation Protection Officer should take part in the planning of activities involving significant exposures, and should advise on the conditions under which work can be undertaken in controlled areas.

Human Resources Development

Training and education in uranium geology and exploration

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Probably even more than for all the other resources, evolution of the scientific research for uranium metallogenesis closely follows the evolution of exploration budgets which are themselves the direct consequence of the metal price on the market. After a strong increase of exploration during the seventies, as a consequence of the 1973 oil crisis, studies and training related to uranium metallogenesis were almost stopped in most countries from the end of the eighties until the beginning of the years 2000. But a very important event for the development of the knowledge about uranium metallogenesis, happened in 1990, with the opening of the Soviet block countries. The huge research effort developed by thousands of researchers and exploration geologists since 1945 became accessible to western countries, and several hundreds of deposits have been added to the IAEA data base UDEPO. It appeared that USSR had mined almost half of the uranium produced in the world at that time, partly from deposits which were not known to have large resources in the western countries. Within the next years the number of publications on U deposits will become exponential in relation with the explosion of exploration budgets, research in the universities, project development in large companies and over 400 junior companies created in the world during these last years, following the strong increase of the uranium prices on the spot market. As a result of the weak exploration and research efforts, skilled professionals in the field of uranium geology and exploration have tremendously decreased from the late eighties to the early twenties. These last years the mining industry has faced a severe lack of experienced geologists. Retired uranium geologists have massively returned to work in the junior companies and as consultants. Vigorous training programs are being developed worldwide, but the needs are still tremendous. Presently, the best training is probably the one made for radioprotection because of the strong existing regulations. A considerable effort has to be made for developing the education in the field of the physical and geochemical properties of uranium, which are very specific to this element, and for the understanding of the various geologic models of U-deposits, those occurring at nearly all steps of the geologic cycle. Such knowledge is required to develop efficient exploration programs and to prevent spending large investments for hopeless targets as illustrated by many case studies.

The United States uranium recovery industry and the current nuclear renaissance – A health physicists perspective

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Concurrent with the recognition that nuclear generated electricity must play an increasing role in worldwide energy supply and in consideration of the new nuclear power plants ordered or planned, the demand for uranium needed to fuel these reactors has already outpaced supplies. Accordingly, the price of uranium (typically expressed as US \$ per pound U_3O_8 equivalent) has increased significantly over the last two years. As a result, numerous new and reconstituted uranium recovery projects are being developed in the United States and in other countries that possess considerable uranium ore reserves (e.g., Canada, Australia, Kazykstan, Mongolia, Namibia, and others). It should be noted that in the United States, the current reactor fleet of 104 operating units, which generate 20 percent of the US's base - load electricity, requires approximately 55 million pounds of U_3O_8 per year, but only about 4 - 5 million pounds per year is produced domestically. That is, over 90 percent of current demand, ignoring anticipated increase in requirements in the near future as new plants come online must come from foreign sources. Domestic uranium production over the last 10 years reached a low of about two million pounds in 2003 and has been increasing steadily since then. Uranium recovery as defined in this paper encompasses conventional uranium mining and milling as well as in situ recovery techniques and the recovery of uranium as a byproduct from other processes, such as phosphoric acid production. Following a brief history of uranium recovery in the US, the paper describes the basic methods and technologies associated with conventional uranium mining, conventional uranium milling and In Situ Recovery (ISR). The "health physicists perspective" is introduced into these discussions by providing summaries of the various radiological environmental monitoring and operational health physics programs that are required for these recovery techniques based on specific design and operational aspects of each. Applicable regulatory guidance and associated "best health physics practices" developed at these facilities are described.

The IAEA support to training and education in uranium production cycle - a new task

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Doubling uranium production within 10 years, between 2005 and 2015, especially after a 25-year-long depression, raises many questions. One of the most important, but still underestimated, is education and training of a new generation of uranium industry workers. Many newly designed operations will cover the production and each of them will need a certain number of professionals, who cannot cover more than one site. There are many limitations in their proper development, such as limited number of those who can teach, train and consult, because they are already busy with their work. Another one is a myth we can simply “buy” them from other mining industries (oil and gas, coal, gold, copper, zinc etc.). All these industries are also developing quickly and are facing similar problems. Creation of an international network for training and education in uranium production cycle activities would be one step forward in resolving their problem.

This new task is proposed for the budget period 2010-11. Currently some of the potential members and contributors are being contacted to discuss and setup the preliminary organisational framework and agenda of actions. Basically a few meetings to cover different topics will be organised by the IAEA including Technical Meetings and Consultancies.

The availability of sufficient numbers of properly educated, trained and experienced personnel should limit the creation of “new” legacies following uranium production. This is important in the current situation as not all existing legacy issues have been satisfactorily resolved and the new ones should not be created.

Cooperation with emerging countries in advanced mining training programmes involving an industrial partner

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The **Centre for Advanced Studies of Mineral Resources (CESMAT)** is a Higher Education Institution in France to train and perform the upper management personnel working in mining, throughout the world. The program of study is comprised of seven separate year long study programs, a network of some 2 300 former students from a hundred countries with whom regular contact is maintained, and a permanent think tank unit that concentrates on the training of mining sector managers. The guiding principle for CESMAT is that cooperation and training hold a special position in French policy concerning relations with mineral producing countries.

Seven programmes have been progressively developed on minerals prospecting and processing, resources evaluation, open cast mining techniques, mining economics, impact of mining on environment, management of closure of mining activities and the role of the State. These programmes bring together ten to twelve engineers or geologists who have already had professional experience. For non-French speakers, a language-training phase of three months may precede the programs. The following specializations are currently being offered:

- Ore Prospecting and Mineral Processing - Nancy School of Geology – CESEV,
- Treatment of Industrial Evolutions and Changes – CESTEMIN,
- Geostatistical Analysis of Ore Deposits - Paris School of Mines - C.F.S.G.,
- Open Cut Mining Operations - Paris School of Mines – CESECO,
- Economic Analysis of Mining Projects - Paris School of Mines – CESPROMIN,
- Mine Safety and Environments - Alès School of Mines – CESSEM,
- Mines Public Administration - Paris School of Mines - CESAM.

Teaching is done both by Institute professors and by public and private sector industry experts. These instructors rely heavily on technical visits and on practical case studies. One specific example is the student research project mentored by specialists in the field, which is oriented directly to circumstances in the student's country. The participation of students in each program is attested to by means of an official certificate. In some cases, this may be accompanied by a diploma from the host school. Tuition for the courses, which runs (around 15 000 €/year) may be covered by CESMAT for students affiliated with public or private mining organizations from foreign, mineral producing countries. Scholarships are also available from French organizations, sources in the student's country of origin, or international organizations such as the EU, UNESCO, UNPD and others.

CESMAT has also built partnerships with mining companies (VALE in Brazil, CODELCO in Chili and AREVA in France) which contribute to sponsor trainees for living cost during their studies in France. AREVA is developing uranium exploration and mining in many countries and has signed cooperation agreement with the government of these countries to provide them technical and financial support for capacity building in partnership with the French school of mines.

Technical Cooperation Workshop

Overview of the recent IAEA national technical cooperation projects on uranium exploration in Argentina

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Since 1993, three national technical cooperation projects have been developed through the IAEA's technological transfer:

- ARG 3/007 "Uranium Favorability and Exploration in Argentina" (1993 - 1996). In the context of this TC project, new skills were developed to carry out the assessment of the uranium favorability of the country. In addition, 140 000 km² of airborne gamma ray spectrometry data were reprocessed and back-calibrated, the Geographic Information Systems were introduced in the exploration projects and new guidelines were defined for the exploration of the sandstone, granite and volcanoclastic geological types of uranium deposits.

- ARG 3/008 "Prospection of uranium and other elements using gamma-ray spectrometry surveys" (2001 – 2004). In the framework of this TC project, new capacities for the detection, processing and interpretation of gamma ray spectrometry data were developed. A airborne gamma-ray spectrometer system was successfully installed and calibrated to increase the national capability for uranium exploration. Moreover, this was a powerful data-supplying for the production of potassium, uranium, thorium and background radioactivity maps for mineral exploration and environmental studies.

- ARG 3/012 "Geology favorability, production feasibility and environmental impact assessment of uranium deposits exploitable by the in situ leaching technology (ISL)" (2007 - up to date). In this project, the areas of interest within the uranium mining cycle of ISL are being evaluated. Regarding the favorability stage, some Tertiary and Cretaceous sandstone units are being investigated through the compilation of previous information, field reconnaissance, the gathering of logging and sampling data from oil wells, petrophysical determinations and petrological studies. According to the present knowledge, ISL should be considered as a sustainable alternative for uranium production in the future of our country.

Technical officer's experience in supporting Technical Cooperation (TC) projects implementation

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The Technical Cooperation Department of the IAEA helps to transfer nuclear and related technologies for peaceful use to countries throughout the world. The TC Programme disburses more than US\$70 million worth of equipment, services, and training per year in approximately 100 countries and territories which are grouped into four geographic regions. With almost 200 staff members, the TC Department works in full partnership with Technical Officers (TOs) from the Technical Departments within the Agency and project counterparts in the recipient Member States. In addition, TC collaborates with the World Bank and other organizations to plan and execute projects in harmony with Member States' needs. Through training courses, expert missions, fellowships, scientific visits, and equipment disbursement, the Technical Cooperation Programme provides the necessary skills and equipment to establish sustainable technology in the counterpart country or region. With more than 800 on-going projects, the TC Programme strives to have an impact on Member State problems that can be solved with nuclear technology.

The role of TOs seems to be just supportive for the entire process. However, do we know, what are the duties of the TO? The role and duties of a TO are usually very much underestimated. Terms as 'technical advice and input' say a little about actual TO's work, who in fact is managing the project, finding and coaching the experts, specifying and organizing expert missions and workshops, working a lot on visits of national consultants and scientific visits, writing terms of reference/statements of work for procurement/subcontracts, performing technical evaluation of tenders, managing the projects dealing with subcontracts, coaching the counterparts, etc., etc. Not having the list above of real TO's duties and activities, one will never estimate in a realistic manner the workload and staff needed or a reasonable number of projects for one TO that can be implemented in a quality manner.

Panel Discussion

Panel Discussion: Introductory Speech:

Building for Success in Troubled Times

G.W. Grandey

Cameco Corporation, Saskatoon, Saskatchewan, Canada

In spite of the dramatic decline of world financial markets and a looming global recession, Cameco CEO Jerry Grandey remains optimistic about the future for the uranium industry. Certainly prudent financial management is required in times of turmoil, but Grandey says it's equally important that those of us involved in the nuclear industry don't get swallowed up by the current culture of gloom, pessimism and fear.

The long-term fundamentals of the industry remain strong. Worldwide demand for nuclear power continues to grow and we know that new uranium production will be needed to meet increasing demand. Utility customers are large, stable businesses that people depend on for electricity – in good times and bad – and we have yet to see any significant chill effect on plans for new reactors.

Nuclear is still a growing industry, although Grandey expects the pace of growth may be more deliberate in the short term.

That's because even the most solid of industries cannot avoid some impact from the global financial crisis. Financing will be harder to come by and companies may have to raise capital by other means. In the uranium production sector, Grandey expects this will mean more joint ventures, asset sales, special equity partnerships, and mergers and acquisitions as companies continue to search for ways to advance projects during these challenging times. Failure to find and develop new mines will perpetuate the imbalance between supply and demand for many years to come.

As the global financial crisis continues, industry players can work together to lay the groundwork to ensure we emerge even stronger. This means focusing on cost control and continuing to reduce our environmental footprint. It also means making the case for nuclear as a clean, green way for nations to stimulate the economy and create jobs.

In short, it is incumbent upon each of us to show the world that investing in nuclear will not only help economies, but also address the pressing issues of climate change and energy security. Once the financial crisis is surmounted, the industry will build on its foundation and move to accelerated growth.

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