Resourcing Future Generations:

A Global Effort to Meet the World's Future Needs Head-On

In the middle of the 20th century, some countries experienced unprecedented improvements in living standards, as measured against virtually any metric: Mortality rates fell, life expectancies rose, and per capita incomes swelled. This dramatic rise was fostered by wartime technological advances — in, for example, radar and magnetometry — that, once applied outside the military, allowed for an explosion in the discovery, production and utilization of water and energy resources as well as numerous mineral commodities, from construction staples to nuclear fuels and metals for high-technology applications.

Some of the prosperity of the developed world, including health care improvements, has spilled over into the developing world, leading to rapid global population growth. Today, 7.1 billion people call Earth home, nearly triple the world's population in 1950. And by 2050, Earth's population will be between 8.3 and 10.9 billion, according to the United Nations' Population Division — an increase, in just four decades, of 17 to 54 percent. One of humanity's great challenges will be to raise living standards further, particularly in less developed countries and regions, meaning continued development in construction, transportation, communications, health care and other sectors. And where there's growth, increases in demand for natural resources will surely follow.

But supplies, of readily available mineral commodities in particular, appear to be limited.

Demand for raw materials like iron ore and metals for advanced technological applications — platinum group or rare earth elements, for example — has been growing steadily, often outpacing the rate at which new ore discoveries are made. And the area available for mineral exploration is decreasing as increased population has led to greater areas utilized for housing and agriculture, often setting those areas off limits to mineral development. Recycling programs and improved efficiency of use have helped offset declining discoveries, but shortages in some major commodities can be expected within decades.

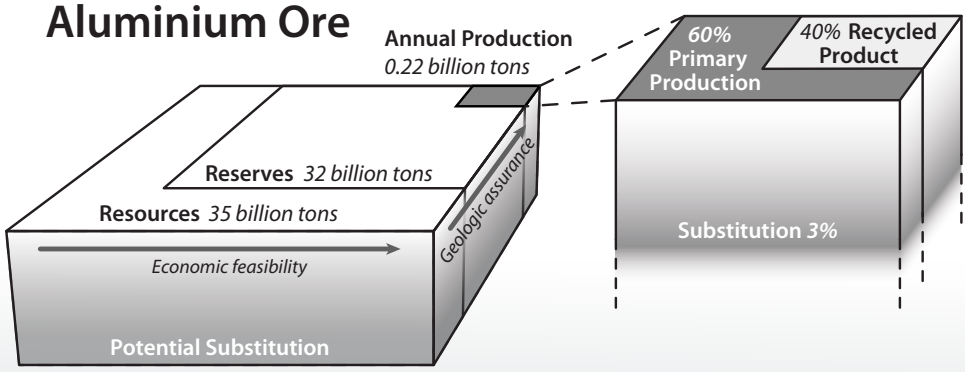
Population, and thus material, growth is dominated by Africa and Latin America, as well as from the BRICS — the major emerging economies of Brazil, Russia, India, China and South Africa. However, in a global market where mineral resources are unevenly distributed and supplies may be subject to political instability, volatile pricing and geopolitical concerns, availability issues are a problem not just for these growing markets, but for the whole world. This global challenge is further complicated by falling discovery rates and increasing access issues partly driven by increasing resource nationalism and expectations of more sustained returns to the regions/nations concerned. All of this is coupled with casual expectations of minimizing lasting environmental and social impacts. In some specific circumstances, commodities are being mined non-commercially to ensure available national supply of critical materials. An aggressive

strategy of change from this status quo is critical as without such change we will not achieve the enormous task of meeting humanity's future needs.

How can the needed mineral resources be delivered to accommodate not only the growing global population, but their right to improve their standard of living? This is a multi-generational issue that brings with it fundamental questions about where stable and long-term supplies will be found, as well as how and by whom they will be extracted in ways that are economically feasible, environmentally sound and socially responsible. Addressing these issues now — given the lag between discovery and production of new sources — is critically important for the world's leaders as well as, of course, its billions of inhabitants.

Tackling such a complex but fundamental problem will require geoscientists of all stripes — from academia, industry and various levels of government. The International Union of Geological Sciences (IUGS) believes that a collaborative, international and broad-based program comprising research, data mining, technical development, outreach and education, among other approaches, can help facilitate the process.

Implementing such a coordinated effort will be a challenge to say the least. But IUGS, with more than 50 years of representing the geosciences globally, a diverse international makeup of member organizations, and its influence in the broader scientific community as part of the International Council for Science, sees organizing this collaborative effort as its role and is dedicated to addressing this challenge. Thus, IUGS, through its New Activities Strategic Implementation Committee (NASIC), is developing a novel global initiative, called "Resourcing Future Generations" (RFG), to bring geoscientists together to address the world's future resource needs head-on.



A conceptual diagram of the global resources, reserves, and production of aluminum ore and its relationship to other influencing factors, like substitution, and the recycling of the end product on primary production demand.

An Ambitious Plan

"There's a need for raw materials to satisfy the higher standard of living that the developing world is coming to expect. Where are they to come from? That's the challenge."

– Edmund Nickless, Executive Secretary of the Geological Society of London and Chair of NASIC

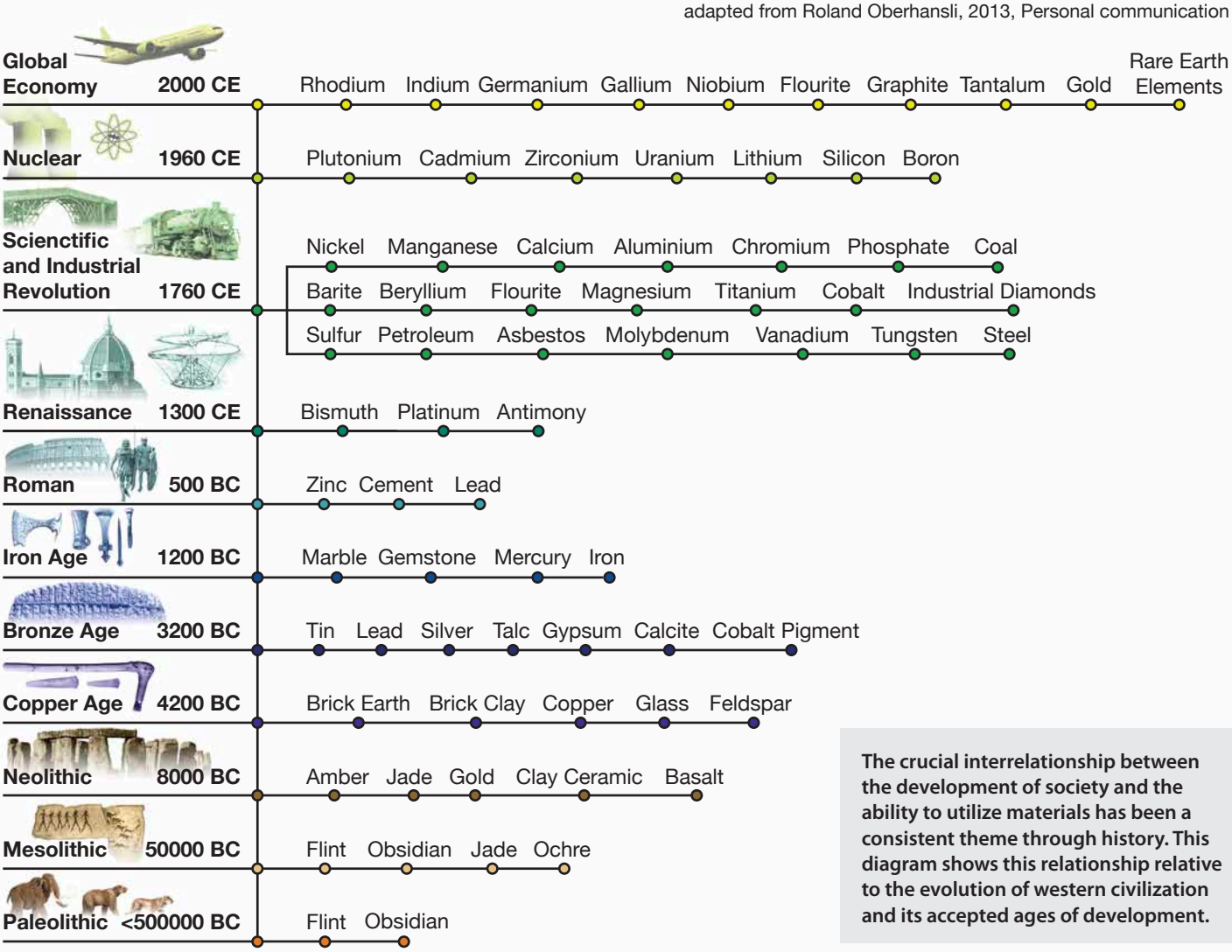
Meeting the multigenerational needs of population growth and to ensure social equity requires, in IUGS's view, four fundamental actions by the geoscience community: 1) comprehensive evaluation and quantification of 21st century supply and demand; 2) enhanced understanding of the subsurface as it relates to resource deposits; 3) assessment of where new resources are likely to be found; and 4) building needed and advanced skills capacity, particularly in developing nations, to discover and responsibly develop mineral resources.

These four pillars are the foundation of the RFG initiative. Infused within the effort as a whole are several additional emphases that are likely critical to RFG's success. Although the overall scope of RFG is global, it seeks to illuminate and address issues region-by-region, be it at the country, continent, or even subsurface depth level. In particular, emphasis should be put on regions that are underexplored. Most easily accessible resources in the developed world have been tapped already, thus the resources for the future lie predominantly in the developing world. Perhaps the greatest challenge is the shortage of the suitable physical and political infrastructure, and the trained workforce in the developing world. Thus, by focusing regionally, RFG can segment its task into achievable goals.

RFG aspires to be of fundamental service to humanity, not to vested interests in resource development. But its success necessitates engagement with

Critical Mineral Commodities through Western Civilization

adapted from Roland Oberhansli, 2013, Personal communication

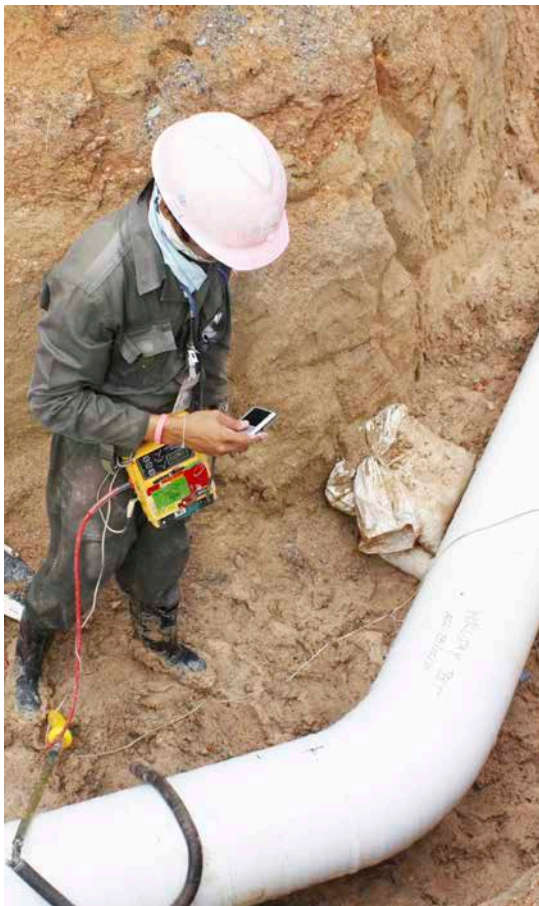


The crucial interrelationship between the development of society and the ability to utilize materials has been a consistent theme through history. This diagram shows this relationship relative to the evolution of western civilization and its accepted ages of development.

industry as well as with governments and the research community, and will require broad data access. RFG is seeking to provide an encompassing mission to harness these and other intellectual and economic resources in the geosciences to address the needs of future generations. To this end, NASIC includes individuals representing a variety of professional and geographic backgrounds. Beyond this, however, IUGS is also seeking feedback about and participation in RFG from a diverse array of parties. This includes not only geoscientists, but social scientists, engineers, economists and others, both from regions that have been historically well-represented and under-represented in past minerals resource efforts.

RFG also seeks to both facilitate new research and understanding, as well as to coordinate access to and integration of data from existing "big data" efforts such as the National Science Foundation's (NSF) EarthCube and the international OneGeology program.

Although RFG is ultimately a problem-solving initiative aimed at ensuring humanity has the resources it needs to prosper into the future, IUGS recognizes that the initiative's success depends critically on its ability to demonstrate its value quickly to both its participants and backers. It must deliver tangible results in the short term. While consideration of future energy and water resources, which of course are intimately linked to mineral exploration and extraction, will be added into the fold of RFG eventually, the initial focus in the first two to five years is on mineral commodities. NASIC has identified proposed activities aligned with the four themes above that, through a global collaborative effort, are achievable in less than a decadal timescale.



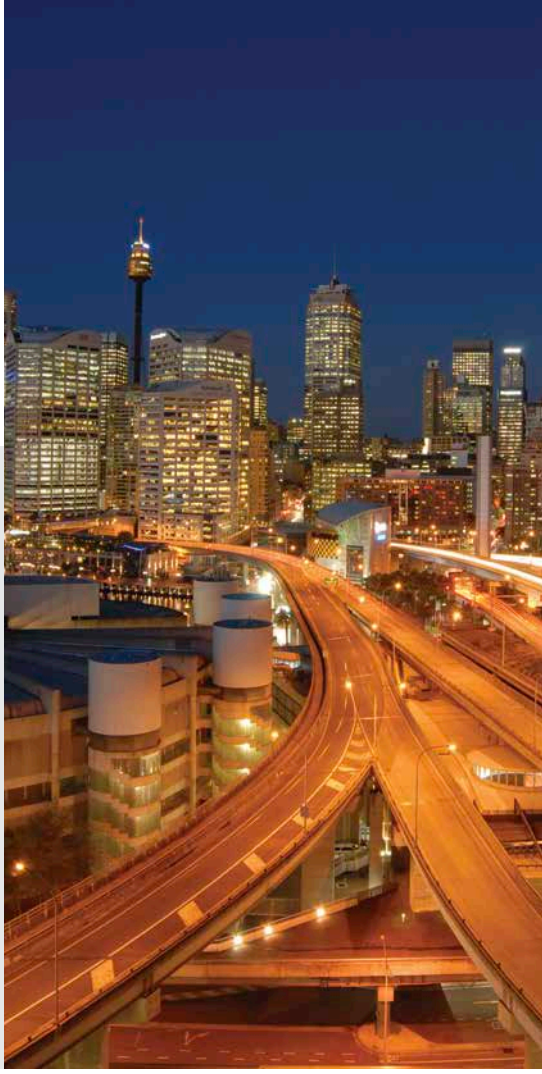
Supply and Demand

The first step toward addressing the world's mineral resource needs for coming generations is to comprehensively understand the available supply and future demand for commodities. The process from discovery to production of new resources commonly takes more than a decade, so the resources needed beyond 2030 need to be evaluated and developed now. IUGS seeks to assess trends in supply and demand beyond 2030, by which time shortages of some major commodities will likely have arisen, given this long lead time for responsible and sustainable resource development.

Detailed understanding of current and potential resource deposits is known for some regions, such as the US, Europe and Australia. This level of understanding does not adequately extend into the developing world, but it must to enable confident global forecasts of regional supply. Forecasts for both supply and demand must also account for projections of advances in technology and changes in economic factors — each of which could alter the landscape of deposits seen as feasible to mine — along with population increase estimates.

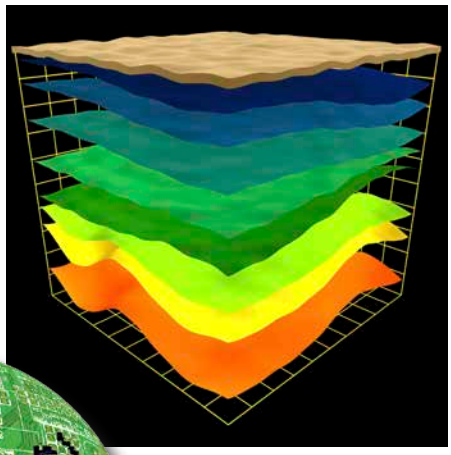
Key activities:

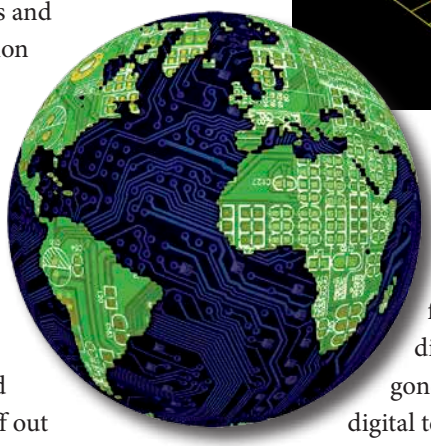
- **Collect and integrate existing resource supply data into a single database**
- **Sponsor new data acquisition about resources in areas where data does not already exist**
- **Develop realistic demand scenarios that account for supply data as well as relevant social, economic and environmental factors**



Studying the Subsurface

Where mineral prospectors once had to rely on interpretations of surface features or perhaps scattered drill holes to deduce what might be hidden at depth, they now have at their disposal a veritable arsenal of geophysical techniques such as reflection seismology and 3-D tomography to magnetometry and gravimetry. Still, as the rate of resource discovery declines and with the expectation that most new deposits will be more diffuse and difficult to locate, there is an ongoing need for additional and ever-more-sensitive tools and techniques to sniff out new finds.





IUGS envisages several key areas of development in exploration methods, including more efficient drilling and inter-drill hole surveying technologies, novel sensors and sensor platforms for identifying deep and diffuse deposits that have gone undetected, and improved digital terrain models to better guide site selection.

At the same time, vast amounts of data are being collected and stored at a rate faster than they can be analyzed. In these data, there is huge potential to both learn more about the subsurface and uncover new finds. Managing this trove, as well as facilitating easy access to and use of this "big data" should be a priority to ensure it is put to good use and not collected in vain.

Key activities:

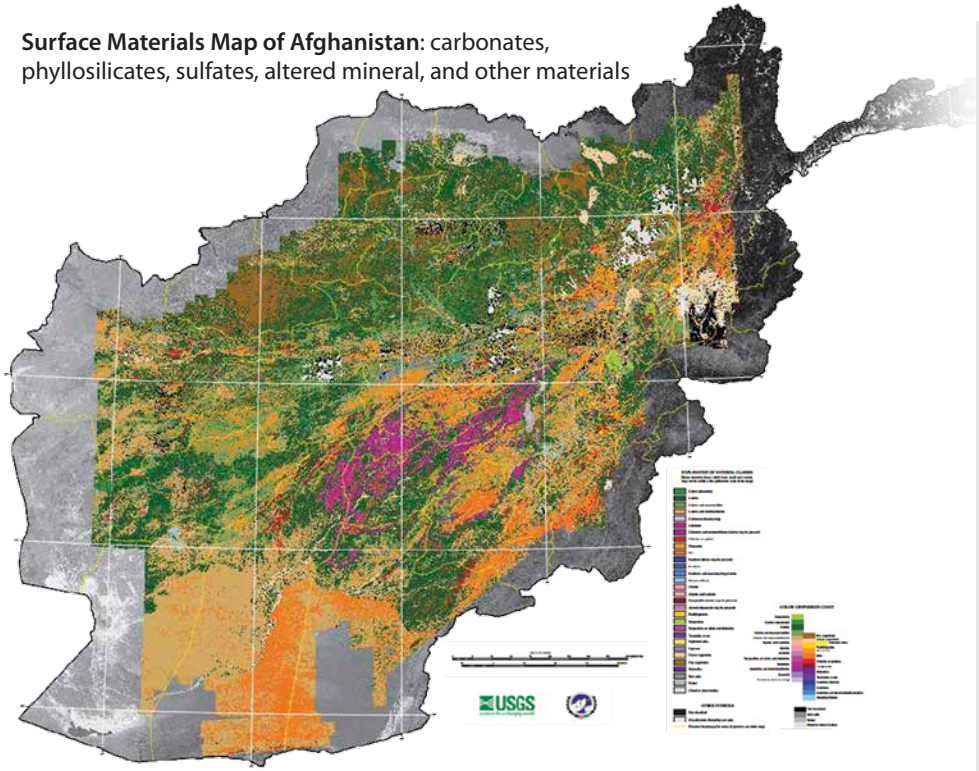
- **Encourage development of novel advanced exploration tools**
- **Maintain a database of the availability and use of current and emerging exploration tools, including details about training opportunities**
- **Promote integration between global observation programs like EarthCube and the Group on Earth Observations, and improve user access to "big data" sources**

Where Are the Resources?

As others have noted (for example, Keith Long of the U.S. Geological Survey), most major rare earth element finds have come by way of accident rather than intent. California's Mountain Pass mine was found during a survey searching for uranium, for example, and China's Bayan Obo district was first mined for iron. The lesson from these examples is that valuable resources may be hiding right under our noses, implying that we clearly don't know all there is to know about mineral deposition processes.

Just as the geophysical and geochemical tools used to study the subsurface must be continually updated and supplemented in the search for new resources, so too must our big-picture understanding of the potential localities and processes of mineral-deposition that have guided past exploration. Declining rates of discovery — though in good measure due to the successes of earlier exploration — underscore that current ore deposit models are insufficient for guiding the coming generations of exploration. In IUGS's view, there is great need for geoscientists to revisit and revise existing models based on new research to gauge their applicability to unexplored regions. There is also need for research into new or little-known types of ore deposits and ore-forming systems.

Additionally, opportunities exist to produce higher-resolution and multi-dimensional geological maps using modern and emerging geophysical methods. Improvements in mapping will further aid evaluations of mineral potential on both regional and local scales. Perhaps most important for such evaluations globally, however, is the production of high-quality maps of underexplored areas, such as Africa and the Tethyan Belt. It is in these areas that large, untapped and relatively easily accessed deposits are more likely to exist than in historically well-explored areas like the Archean craton and Australia, where future exploration will likely need to focus increasingly on deeply buried deposits.



Surface Materials Map of Afghanistan: carbonates, phyllosilicates, sulfates, altered mineral, and other materials

Key activities:

- **Promote innovative approaches to improve current and spur new understanding of how and why mineral deposits occur where they do**
- **Facilitate access to archived and scattered databases of geological and geophysical data to help in refining ore deposit models and geological maps**
- **Compile existing geological maps for under-explored regions, particularly Africa and the Tethyan Belt, and sponsor new mapping campaigns as needed**

Building Support and Capacity in the Developing World

In 2010, extremely high rates of child mortality in villages in the Zamfara region of Nigeria brought worldwide attention to the hazardous practices of artisanal gold mining. The rudimentary tools and techniques of the trade, which brought in only subsistence wages for the villagers, were exposing children and adults alike to highly toxic levels of lead, which occurred in abundance alongside the concentrated deposits of gold. Aid groups helped institute simple best-practice techniques — keeping mining activities out of homes and away from children, and washing dirty clothes to minimize the spread of lead-laced dust, for example — which have helped mitigate the issue. But these practices do not offer a large-scale solution for countries or regions seeking to expand considerably and institutionalize mining operations.

Parts of Africa and elsewhere in the developing world undoubtedly host rich, untapped mineral deposits, but many of these areas lack the infrastructure, governance and trained workforce necessary to undertake the sort of large-scale mining efforts that can responsibly and equitably supply growing populations. Given RFG's emphasis on expanding mineral exploration in the developing world, building capacity and support for such efforts is imperative. Through technical development and outreach programs, RFG seeks to improve the ability of developing nations to create world-class and regionally self-sufficient mining industries.

Additionally, negative perceptions of mining persist in many areas, flamed by connotations that it is environmentally or socially damaging by nature, and by tensions between mining activities and other land uses like agriculture. (These sentiments are not exclusive to the developing world, of course.) Stressing that mining can produce broad economic benefits while being pursued in responsible manners will be paramount to the success of such efforts.

Key activities:

- **Collect available resource supply data and sponsor new regional-scale assessments to locate potentially resource-rich areas as a first step to better characterizing underexplored areas**
- **Encourage learning opportunities in which students from developing countries can gain and subsequently return home with expertise in geology, engineering and other mining-related fields**
- **Initiate public outreach programs to combat negative associations with mining and promote the benefits of responsible and well-governed mining industries**

Questions Moving Forward

"When all is said and done, we want an initiative that helps humankind and a strategy that academia, government and industry see merit in and to which they're anxious to collaboratively contribute."
– Pat Leahy, Executive Director of the American Geosciences Institute and member of NASIC

IUGS is off to a positive start in crafting the RFG initiative, but it is still a work in progress. Some of the challenges to its implementation are self-evident and other challenges are certain to arise. Though IUGS lacks the resources to carry out RFG's ambitious goals independently, it is through its ability to muster its member organizations and geoscientists like you to participate in RFG that will bring it to implementation — beginning in 2014.

But now is the time to take ownership as a member of the global geoscience community, and a member of the human community, to help craft the initiative. As such, IUGS is interested in hearing feedback from academia, industry and government, both generally and in response to the following specific questions:

Are the scope, themes, goals and potential benefits and outcomes of the RFG initiative clearly articulated?

Of the four themes outlined, which is (are) the most important to achieving the RFG initiative's overarching goal of helping address the world's future resource needs?

Under each theme, which activity/ies is (are) most important to achieving the goals outlined? Which are the most and least likely to be realistically achievable within a two- to five-year time frame?

Is this initiative worthy of and/or likely to garner support from geoscientists in academia? In industry? In government or geological surveys? Please explain why or why not.

Describe what you envision as the appropriate role of IUGS in carrying out the activities outlined in the RFG initiative?

To what extent do you think non-geoscientists — engineers, social scientists, economists, etc. — may be of value in helping the RFG achieve success?

NASIC wants to hear your views. Please send comments to edmund.nickless@geolsoc.org.uk. Thank you.

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