After the Storm
Charting a Career in Minerals Exploration into the next 20 years

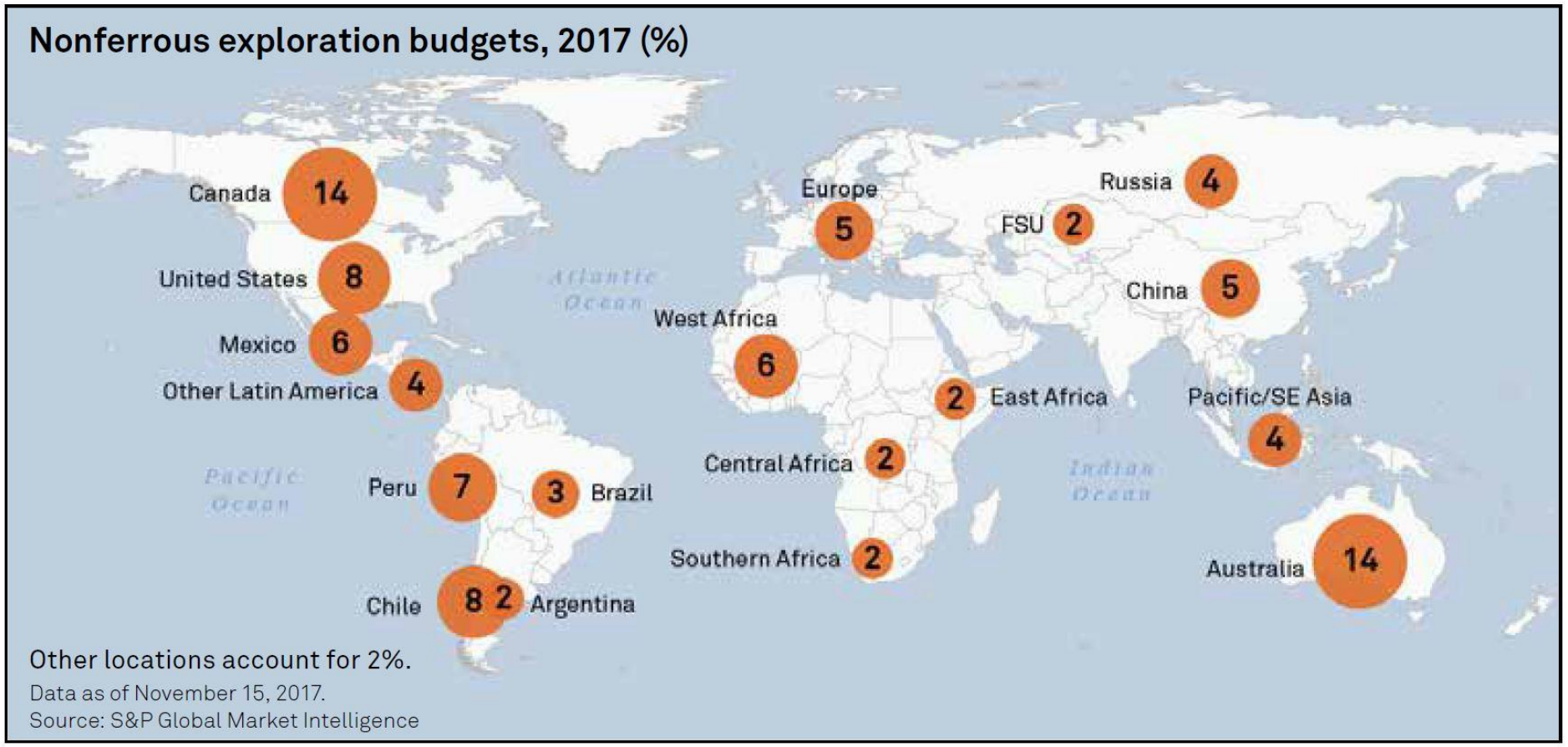
Ken Witherly, Condor Consulting. Inc

December 12, 2018

Minerals Exploration

What is it?

The search for new economic mineral deposits



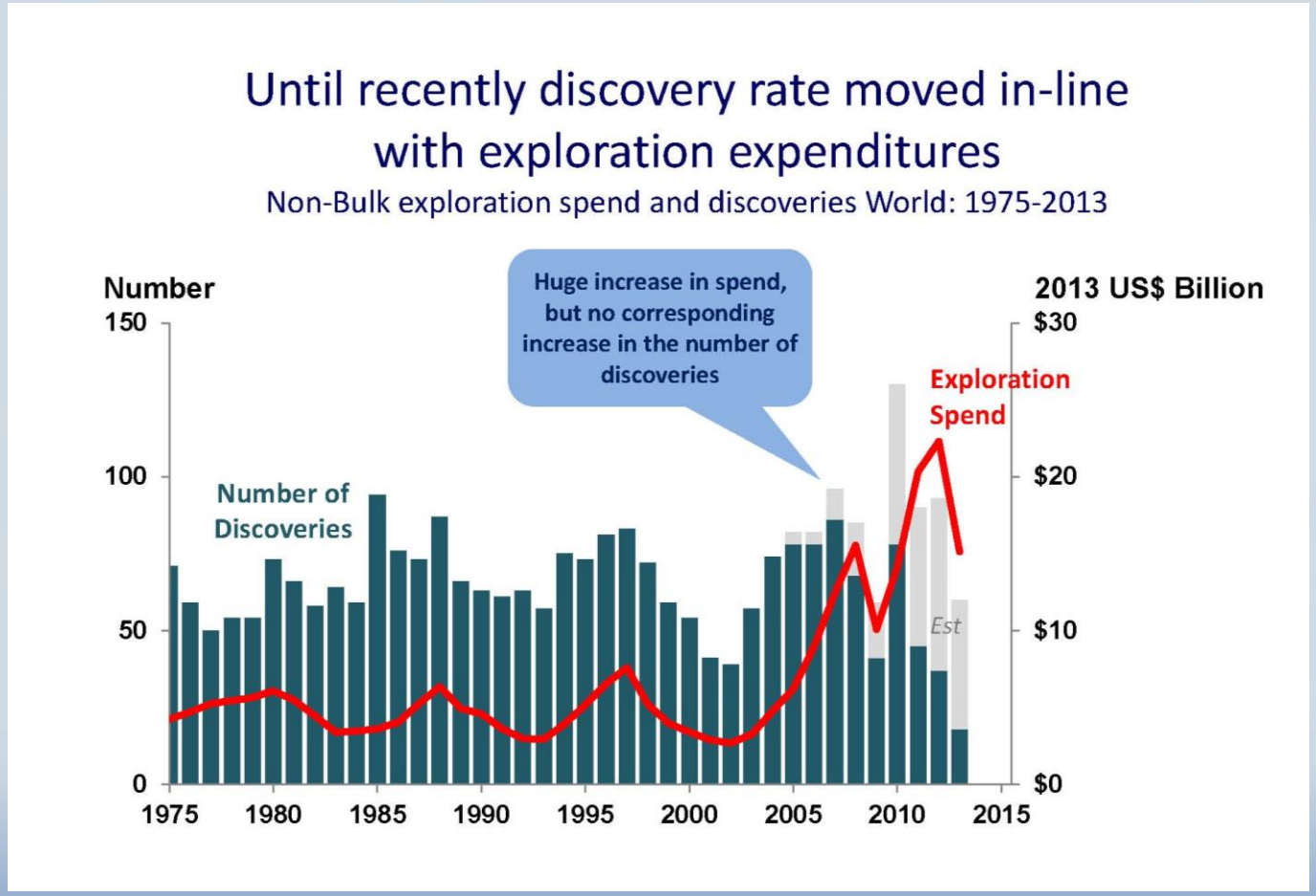
Who is doing the work?

Companies-Majors/Juniors

Majors: These are typically large publically traded companies who have a number of deposits and produce a variety of mineral types.

Juniors: The definition is not so exact as it can include companies with a limited amount of production (1-2 small mines) as well as companies which draw their entire fiscal support from equity obtained off the stock market or from private investors.

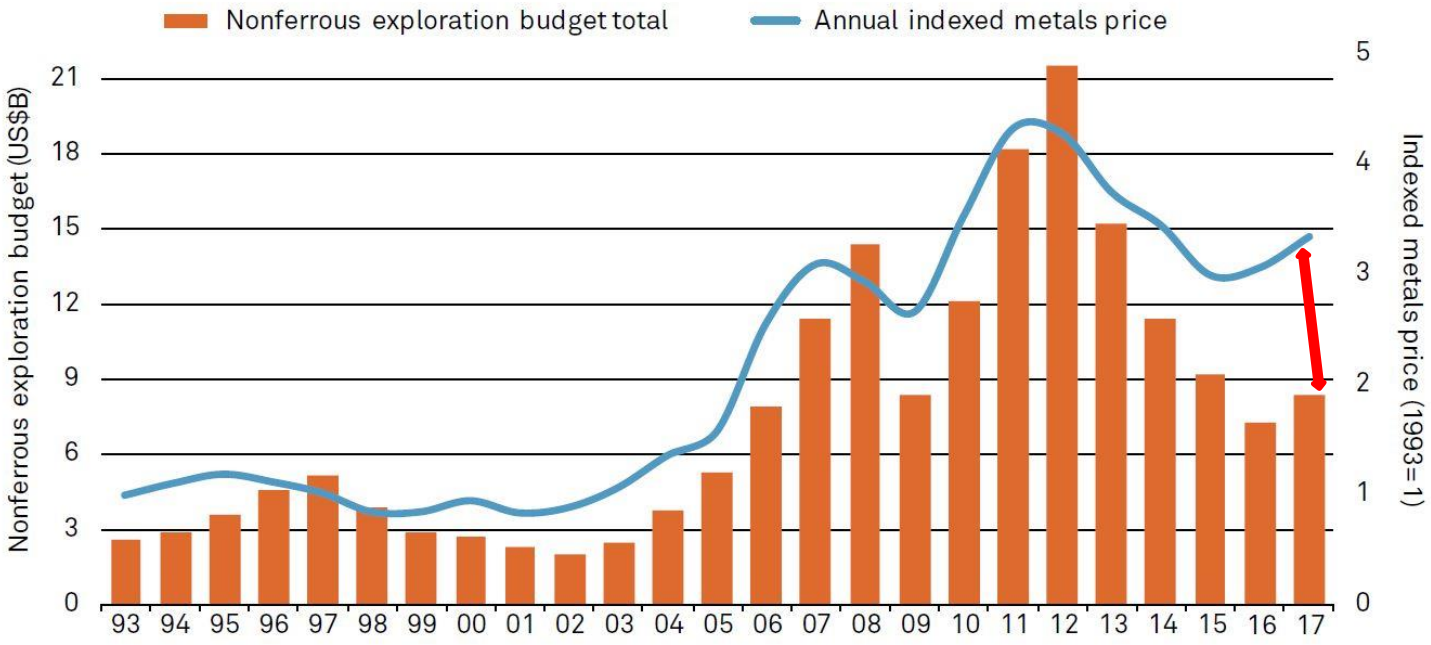
How much is being spent? What has been achieved?



From MinEx- R.Schodde

How much is being spent?
Slight uptick in past two years

Global nonferrous exploration budgets



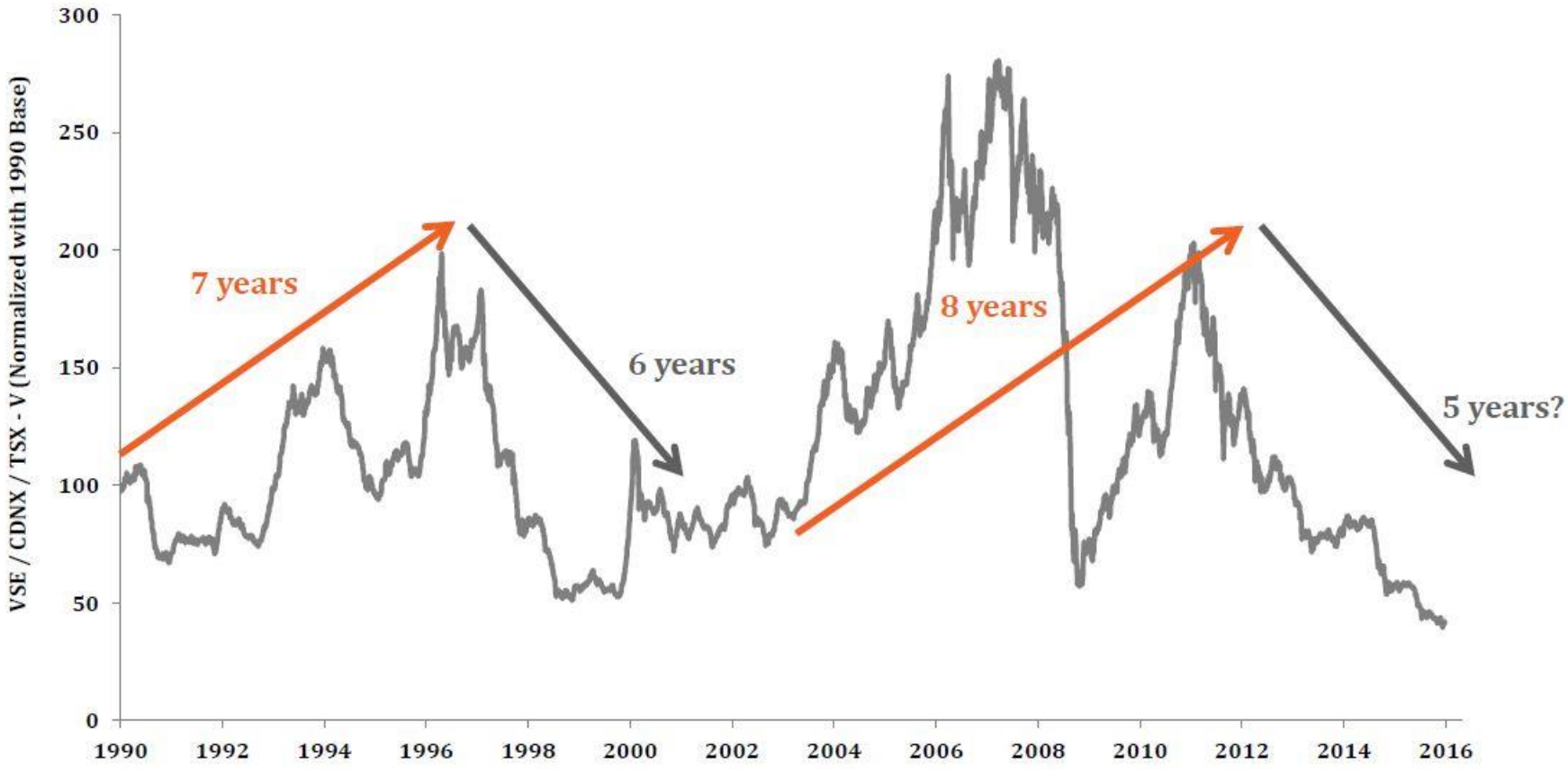
Date as of January 31, 2018.

3,000+

companies surveyed for 2017 exploration budgets

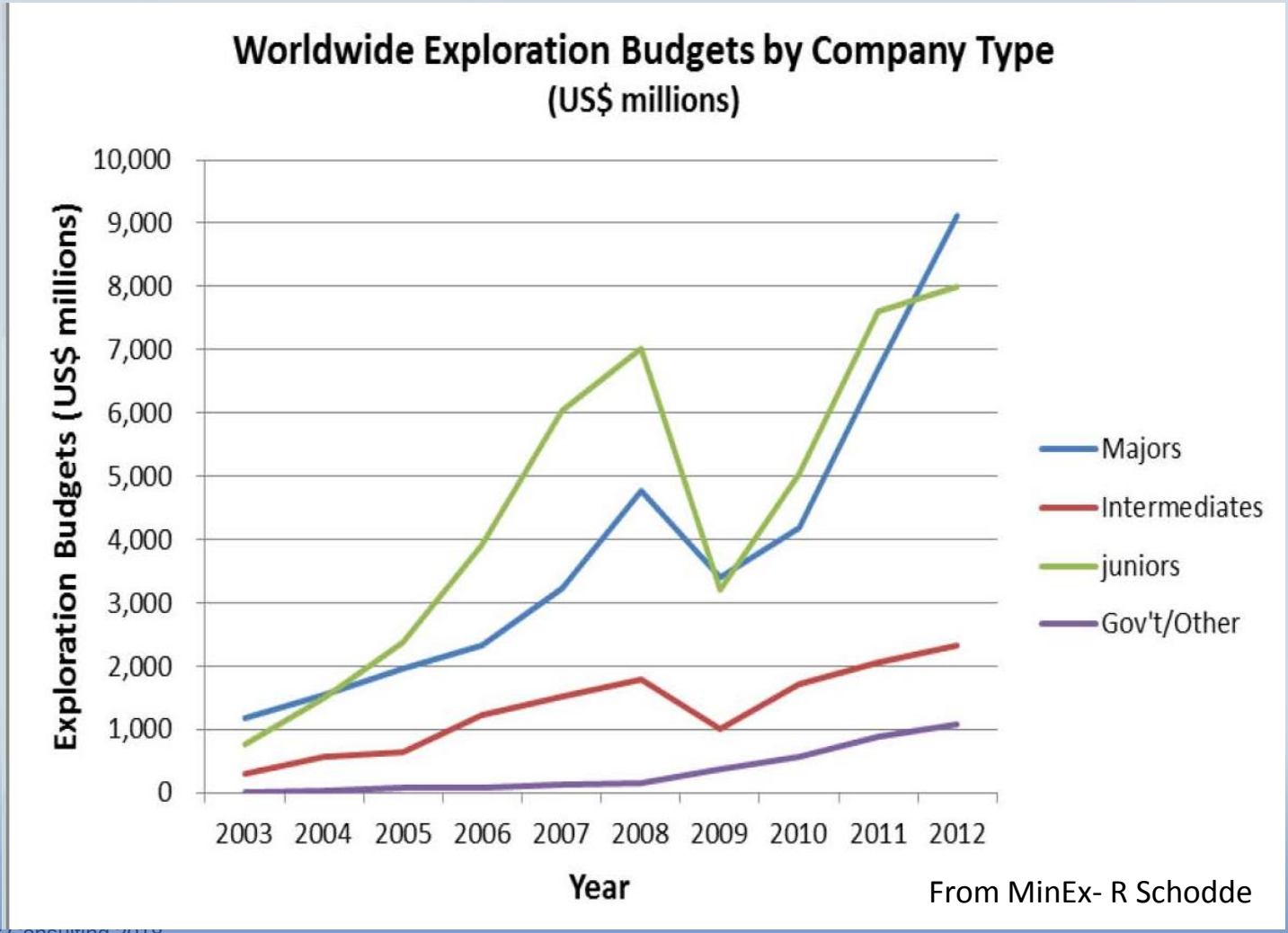
Mining-a business with cycles

Historic Mining Equity Cycles



- The average bull trend is 7.5 years, with 11.7% CAGR
- The average bear trend is 6.5 years, with -20.6% CAGR

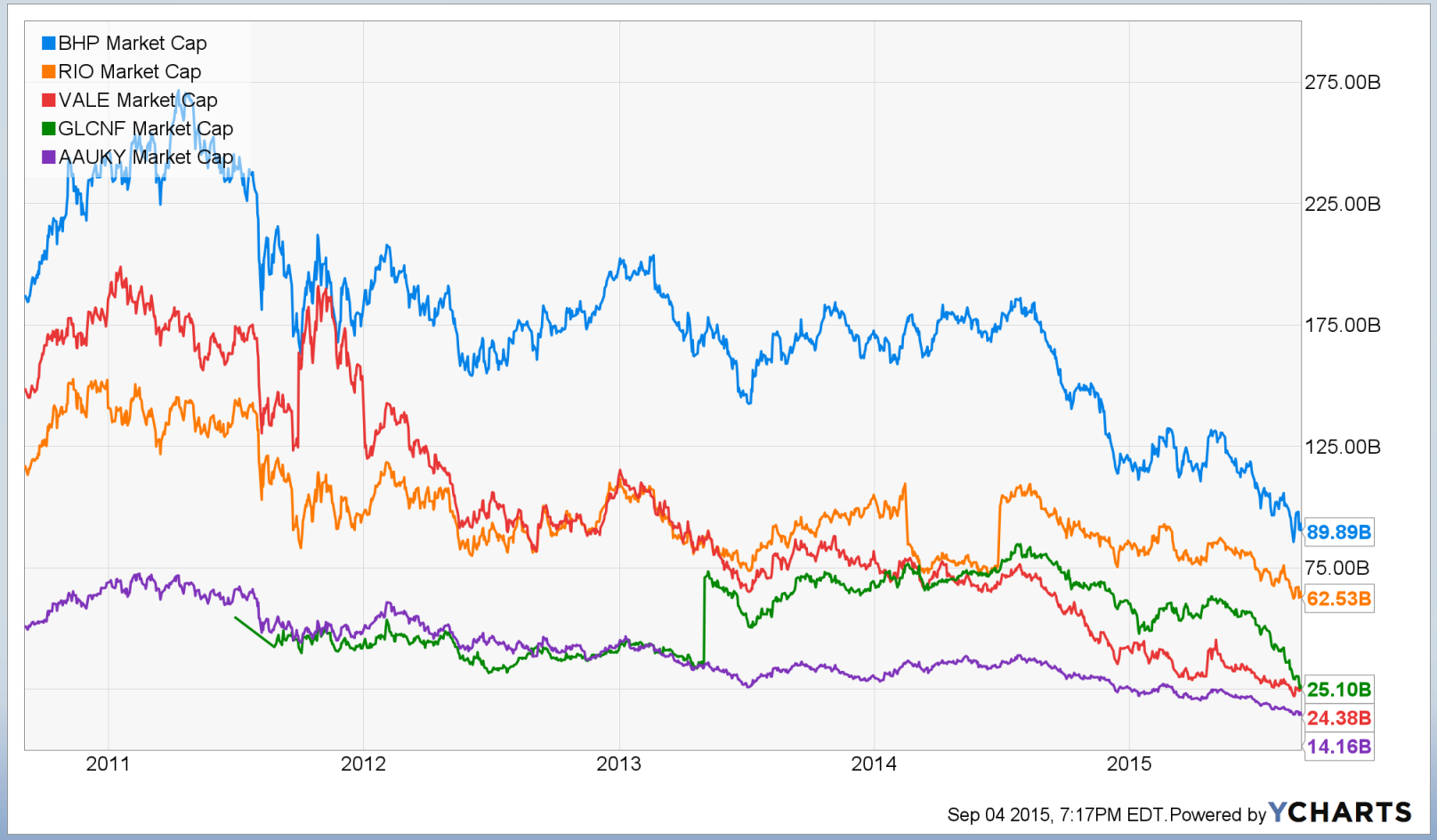
How much is being spent? By who?



From MinEx- R Schodde

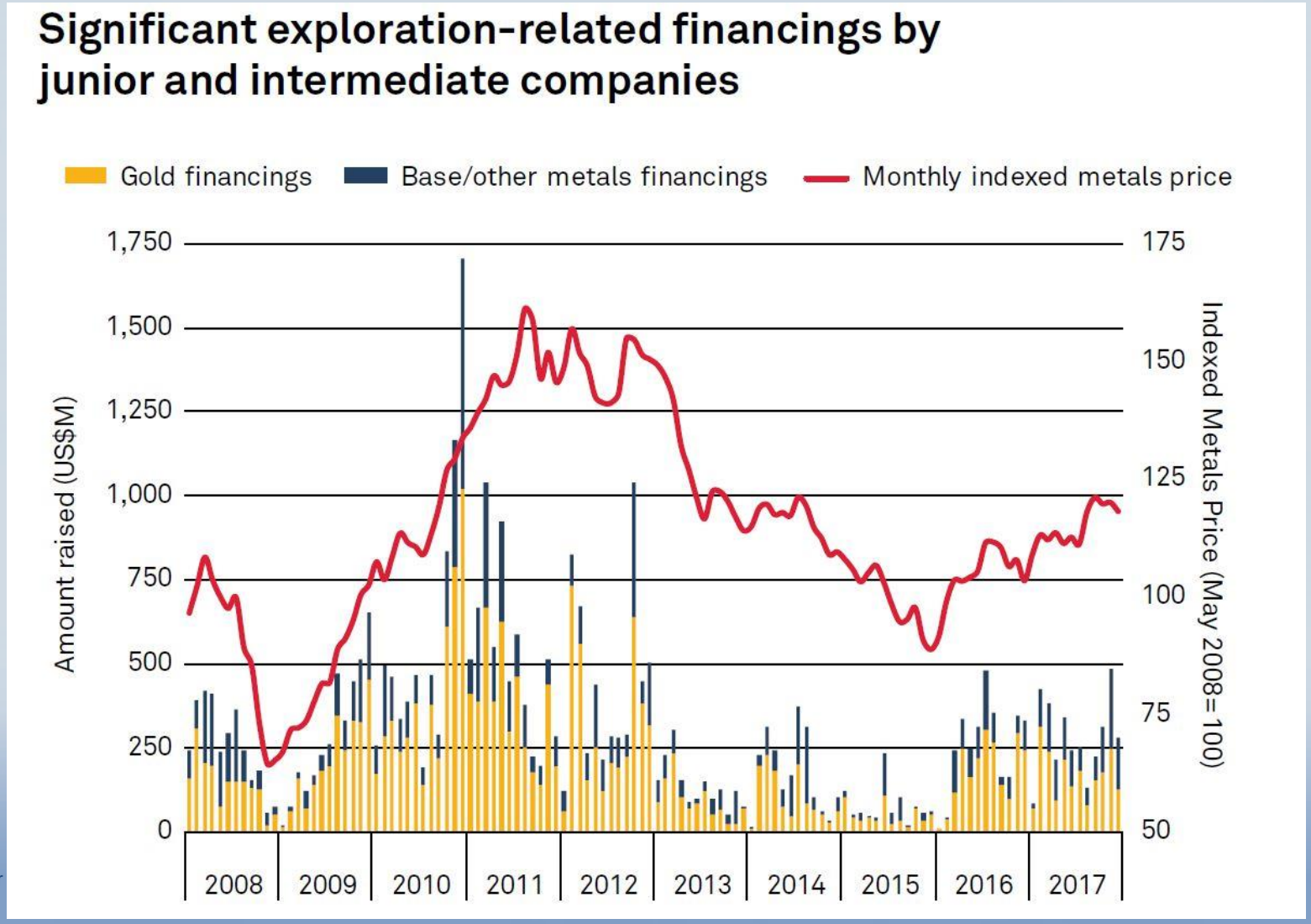
Who is doing the work?

Majors have not a good time of it in the past 5 years



Who is doing the work?

Juniors are having a worse time



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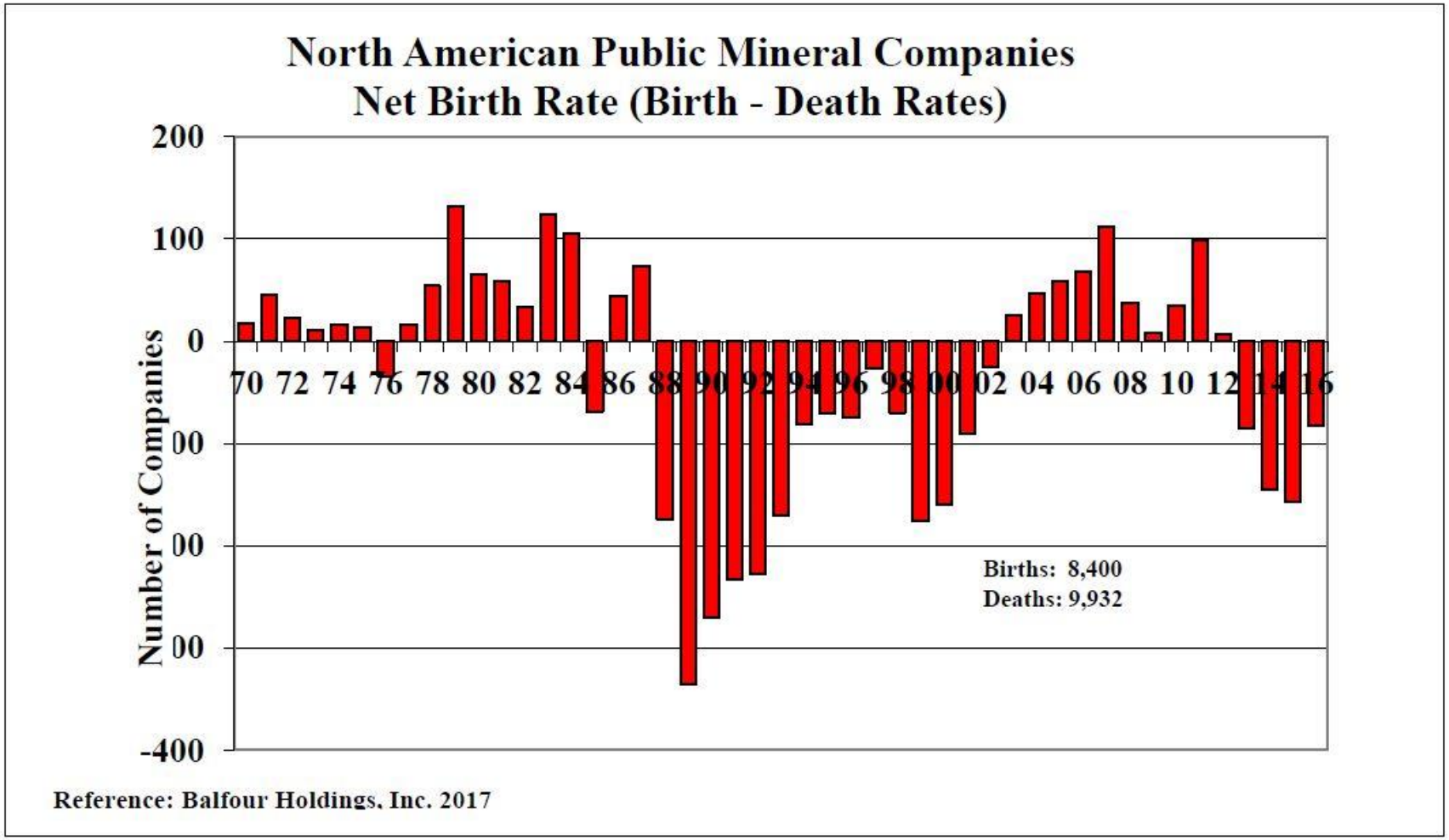

Who is doing the work?
The explorers

Historically the majority of exploration geoscientists graduated from schools in NA/Britain/Australia/South Africa.

As well, the majors were the primary employers of new graduates and maintained offices in all the regions they explorered in. BHP Minerals in 1999 had 42 offices and 750 staff in over 20 countries. Now they have ~5 offices and a staff of <100.

Juniors tended more to retain consultants and contractors and are significant employers to support field programs.

Who is doing the work?

The explorers-how many? Where?

Exact numbers of practicing exploration geoscientists is hard to define but the following estimates are likely within ± 20%. This does not include economic geologists working for governments or in academia.

Canada/USA-2,000
Australia-900
South America-300
Europe-100
Africa-500

There are large numbers in FSU and China and in Russia, some work for private companies; in China however, almost all would be working for state-controlled entities

Who is giving guidance?

For this talk, I contacted ~80 colleagues with a collective experience of about 2,500 years in minerals exploration. I received replies from the majority of these people and their input has gone into this assessment.

Who should you listen too?

Society of Economic Geologists
Special Publication 9, 2002, p. 1–16

Chapter 1

Trends and Forces in Mining and Mineral Exploration

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Consulting Geologist, 4221 S. Yukon Way, Lakewood, Colorado 80235

Special Publication 12, 2006, pp. 171–192

Chapter 9

The Human Face of Economic Geology: Education, Careers, and Innovation

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What is happening?

1) The chronic shortage of talent at all levels due to the exiting of the baby boomers and the decline in new graduates in virtually all aspects of the industry.
2) The lack of quality assets to replace many of the deposits now being mined.
3) The poor long-term fiscal returns on most projects in the mining industry.
4) The enormous global appetite for raw materials that will extend over at least the next 50 years.

What is happening?

1) The chronic shortage of talent at all levels due to the exiting of the baby boomers and the enormous decline in new graduates in virtually all aspects of the industry.

The departure of the baby boomers is ‘inevitable’ and with it a huge amount of experience. On-the-job training and mentoring are seen as a way to ‘pass along’ important knowledge but much less of this is now possible due to majors cutting back on exploration. In the feed-back received, a number cited that they did not see there being a shortage of new graduates but rather there being a lack of suitable training opportunities.

What is happening?

2) The lack of quality assets to replace many of the deposits now being mined.

This is not an across-the-board issue but affects some commodities much more than others. The future for gold (roughly 40% of the exploration spend in 'normal times') looks challenging as grades have been falling for decades and most of the easy to find deposits have been recognized. Development times have inflated and basically none of the major producers are finding enough to replace what they are currently mining. Purchasing assets has 'worked' historically but lowers the overall profitability and there are fewer 'good deals' available. Diamonds is another commodity that discovery has failed to keep up with demand. For the main base metals such as Cu, Zn and Pb, the story varies. For iron ore and coal there are no shortages and hence little real exploration as a consequence.

What is happening?

3) The poor long-term fiscal returns on most projects in the mining industry.

The historic ‘rule of thumb’ is that 1:1,000 prospects turns into a mine. Recent analysis suggests however, that only a small fraction of these actually turn a reasonable profit. This combined with an almost universal behavior of mining firms to purchase marginal assets at market peaks means many companies have saddled themselves with sub-par assets. Many are now trying to adjust their portfolios but it is hard to sell an asset that loses money for anywhere near what was paid for it initially.

What is happening?

4) The enormous global appetite for raw materials that will extend over at least the next 50 years.

There is genuine demand for virtually all commodities for the foreseeable future. Many resources currently defined will not likely to be mined due to issues beyond the industry's control (i.e. Pebble); this means more viable deposits will have to be found.

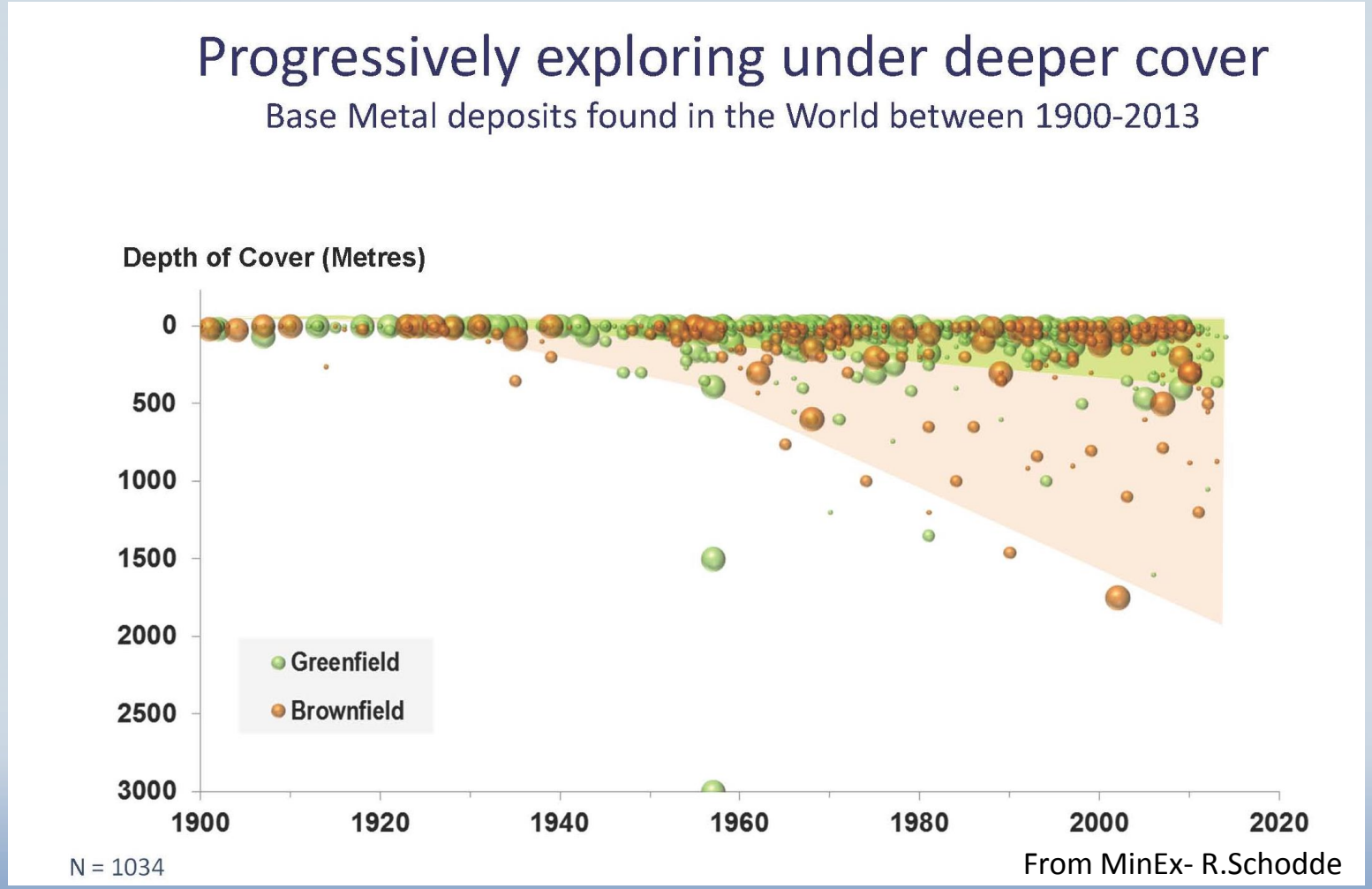
What is happening?

The macro scale factors support the need for minerals exploration into the foreseeable future. However, there is considerable ‘churn’ within all sectors of the industry at the fiscal level, corporate governance and social license. Until the industry can reach a degree of stability, it will be hard for them to invest much in their future (or yours).

The Junior sector has suffered a huge loss of support from investors (individual and institutional) due to what was see as their profligate ways on the last decade. While market confidence will return (greed overcomes pretty much all other sentiments eventually) many of the companies are run by baby boomers about ready to head out the door. Opportunity beckons…

What is happening?

Targets are getting deeper



A Job? A Career?

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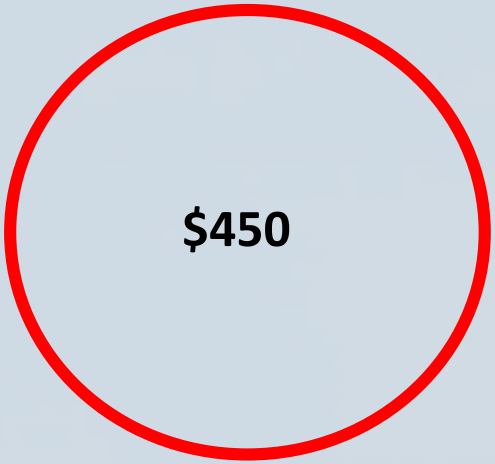
$425

$450

A Job? A Career?

$425



A Job? A Career?

$425/month

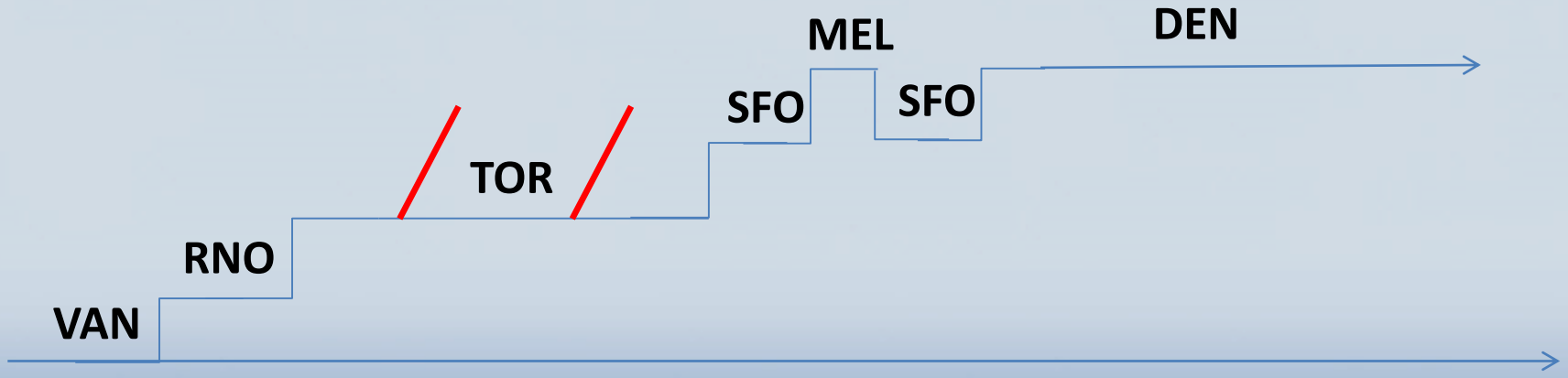
$450/month

Geologist

Geophysicist

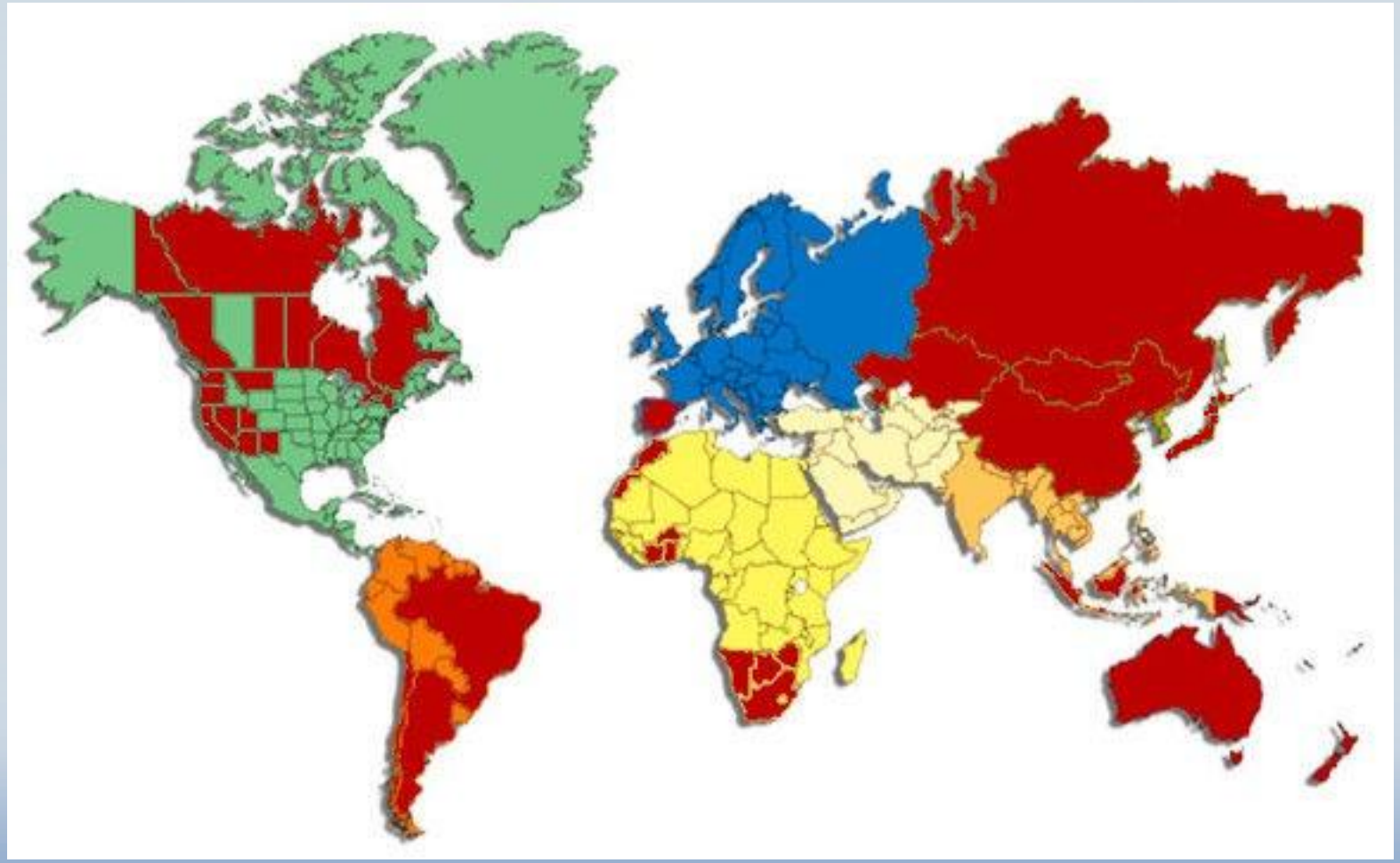
KEW-Career Trajectory

UDC GE BHP CCI



1970 1980 1990 2000 2010 2015

KEW-Where I worked physically (in red)



Passion

Solving problems

Dave Lowell

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Nine rules for exploration success from the world's best mine finder

Michael Allan McCrae | October 28, 2015

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Dave Lowell walks his ranch south of Tucson. Image from YouTube/CEO.ca.

Dave Lowell

1. Ore is rock which can mined at a profit. Low grade is sometimes mineable, and high grade is sometimes not.
2. Mines are found in the field, not the office
3. Mines are now almost always found by drilling holes, so if no part of the budget is spent on drilling there is almost no chance of success. (Pierina was the rare exception.)
4. Exploration is a cost/benefit business. Expensive high-precision core drilling is often used when low-precision low-cost rotary drilling would suffice. In the Atacama Project we spent $3 million on wide-spaced rotary drill holes. If we had used core holes our budget would have run out when less that half the holes were drilled including those that found the Escondida and Zaldivar orebodies. The same logic applies to all other exploration costs.
5. High-tech devices and geophysical surveys are very rarely of value in mine discovery. There should be an almost metaphysical communication between the rocks and the successful explorationist in which the rocks talk to the explorationist. If he turns part of this job of geological mapping over to a high-tech gadget, he may look good to uniformed management, but he is less likely to find a mine.
6. It is important to have a good understanding of the target he is looking for, including understanding some mining engineering, metallurgy, mine finance, and mineral economics. He is not looking for a scientific curiosity; he is looking for a mass of rock which can be made into a mine. I believe my mining engineering and mine production work has been very important in my exploration success.
7. Mineral exploration, like investing new blockbuster drugs, has a very low probability of success. Only one out of three hundred to fine hundred attractive targets become a mine. You have to accept the fact that you usually be wrong. I'd guess that only one out of thirty well-trained exploration geologists ever actually find a mine. However, if an explorer has found one mine, statistically he is likely find others.
8. Finding mines is a high-risk business. In addtion to the geological risk are the political risk, the metal price risk, the mine financing risk and the timid, incompetent management risk. Success is the summation of a list of well-evaluated risks.
9. My last facto, which you don't find in training manuals or classroom or mining articles, is the freedom to plan you own exploration project without interference of the company rules or tradition or interference by supervisors who are as good as prospector as you.

A Job? A Career?

2,500 years of advice in 4 bullet points!

1) 3-5 year mini careers may be more the norm in *any industry* these days, based on some of the stats I've seen….so not that much different.
2) Marketability in exploration will depend more and more on mastering multiple skills, including:
   - Traditional fieldwork (still critical) and core-logging
   - 3D Deposit modeling (both constructing quality sections/plans and integrating them into a digital model)
   - Data integration: geophysics, geochemistry
   - Basics of rock mechanics, metallurgy etc.
3) "Soft" skills
   - Mobility
   - Language(s)
   - Social/community relations/environmental
4) Still an exciting and fascinating career

Samarco (Brazil)
November 2015

Mt Polley (BC)
August 2014

Social License at Risk

LETTER TO THE EDITOR

Why Mount Polley's tailings are not toxic

The Mount Polley copper-gold mine operated by Imperial Metals processed a form of ore related to an alkali intrusive. This type of ore is typified as having a low content of sulphur and is not associated with significant quantities of deleterious elements.

The ore when mined contains approximately 0.30% copper occurring in the form of copper sulphide (predominantly as the mineral chalcopyrite) with accessory gold in the copper minerals.

The processing entails grinding the ore and then removing the copper sulphide and then depositing the residual constituents, largely feldspar, to the tailings storage facility.

Imperial's website provides an analysis from 2013 of the chemical parameters of the tailings solids.

It is interesting to compare the heavy metal content (arsenic, mercury and lead) of this analysis with results from an extensive database of naturally occurring stream-sediment values in a pre-mining survey completed in 1981 by then Energy Mines and Resources Canada and the B.C. Ministry of Energy Mines and Petroleum Resources (*The National Geochemical Reconnaissance Survey*, Quesnel Lake Sheet, open file 776).

In the 1981 survey 1,226 stream-sediment samples from the survey area were analyzed for an extensive suite of elements including arsenic, mercury and lead. Arsenic has an average value of 6.2 parts per million (ppm) for the 1,226 sample 1981 population varying from a low of 0.5 ppm to 750.0 ppm in a stream located 26 km northeast of the Mount Polley mine. The Mount Polley tailings solids contain 10.6 ppm arsenic. Mercury has an average value of 56.4 parts per billion (ppb) for the 1981 population varying from a low of 10 ppb to 3,400 ppb in a stream located 44 km northwest of the Mount Polley mine. The Mount Polley tailings solids contain 70.0 ppb mercury. Lead has an average value of 7.1 ppm for the 1981 population varying from a low of 1 ppm to 330 ppm in a stream located 45 km northeast of the Mount Polley mine. The Mount Polley tailings solids contain 4.9 ppm lead.

Moreover the Mount Polley tailings contain 2.67% calcium which prevents the tailings from becoming acidic and thereby leaching significant quantities of residual metal.

The tailings essentially constitute a synthetic feldspathic calcareous sand deposit.

James Morton, P.Geo.
North Vancouver, B.C.

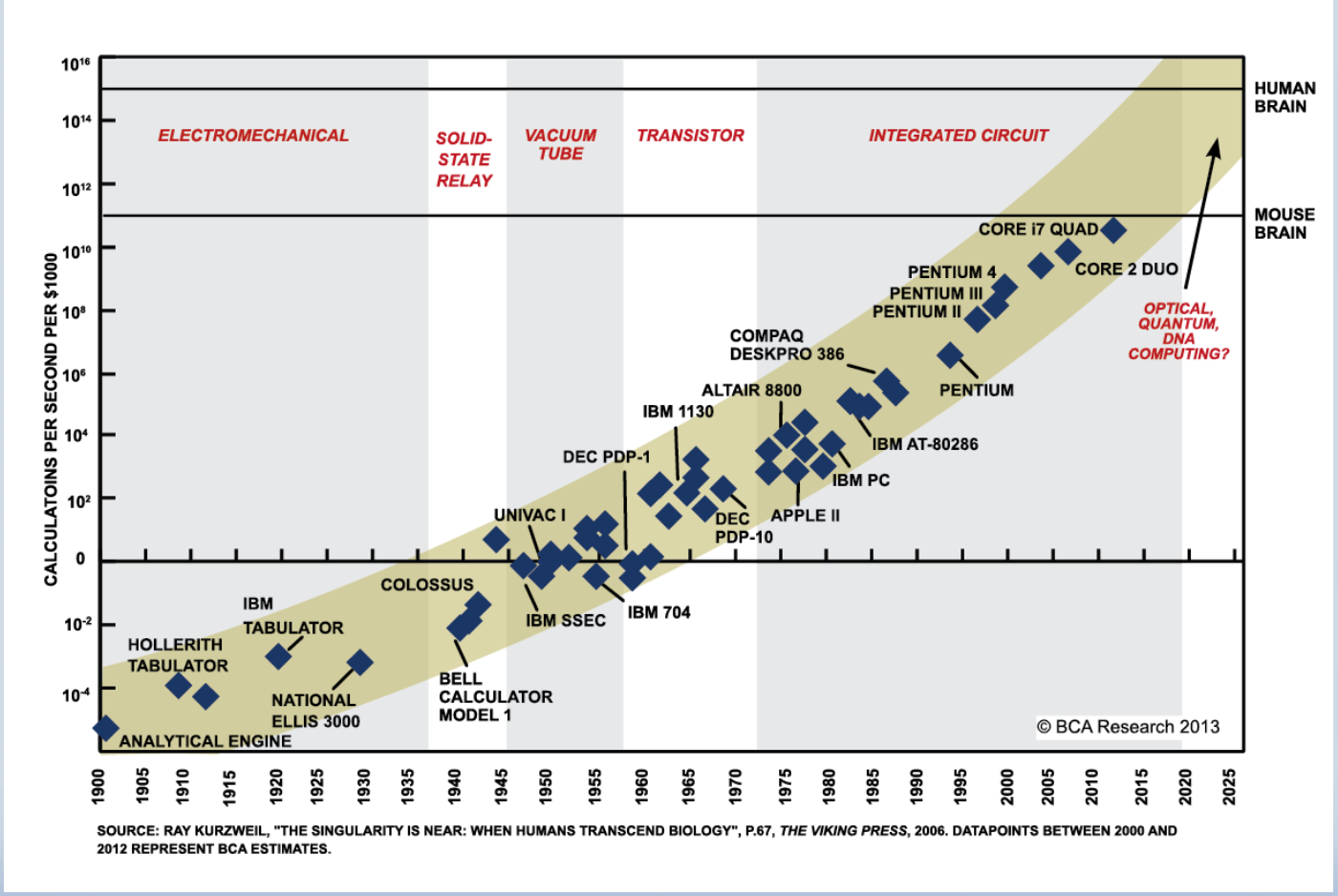
A Job? A Career?
Issues

1) Mentoring was cited as very important but remains a real challenge as major companies have downsized. Also, baby boomers are not really good with social media.
2) Travel can be significant.
3) Mini-careers (aka Geo-Über) could be the norm for many; gaps between work can be very stressful. Implicit with this is the need to be entrepreneurial.
4) Timing-many flagged that timing had been very important in their careers; while not always something that can be controlled, keeping a 'sharp look-out' is always advisable.
5) Data integration will be a major issue/challenge/opportunity

Challenges/ Issues

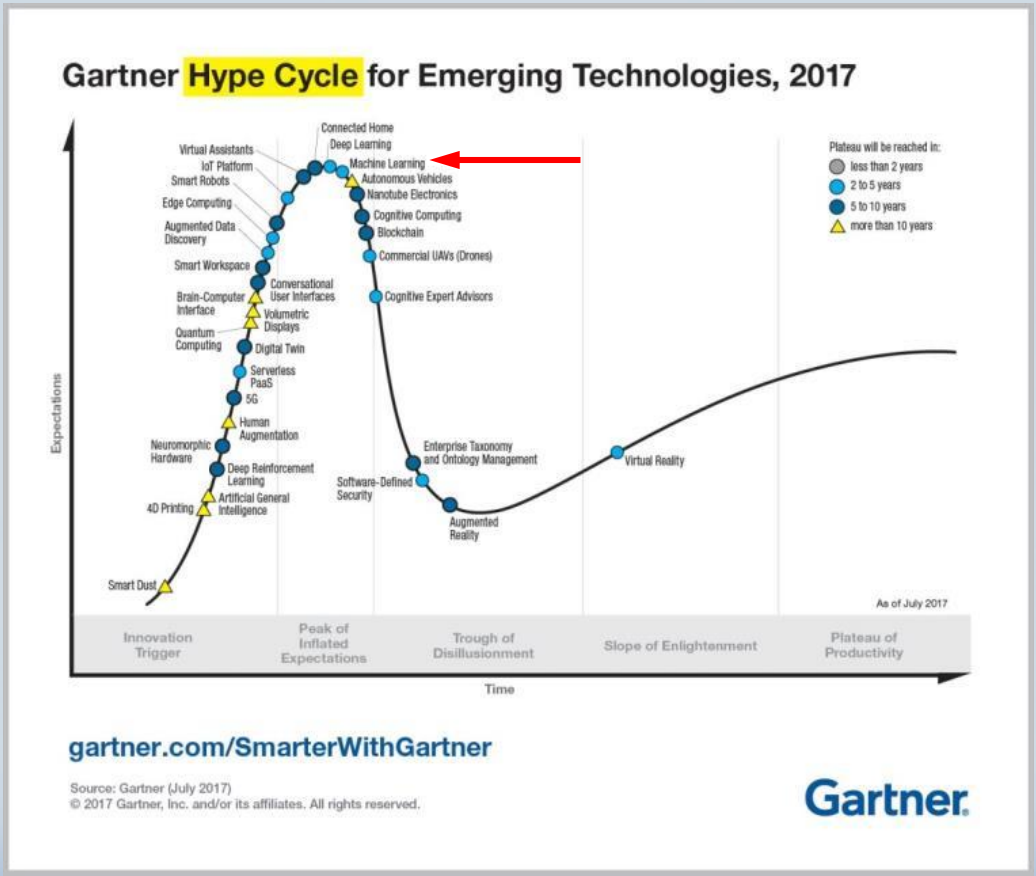
1) New technologies-AI
2) Drilling technology
3) Keeping people in the loop

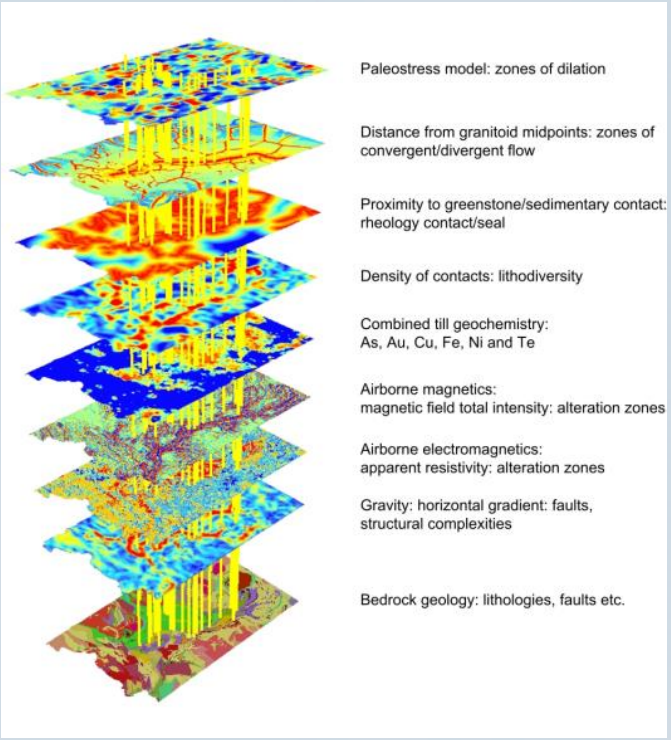
Technology/engineering – the enabler



Check this out → https://www.quantamagazine.org/job-one-for-quantum-computers-boost-artificial-intelligence-20180129/

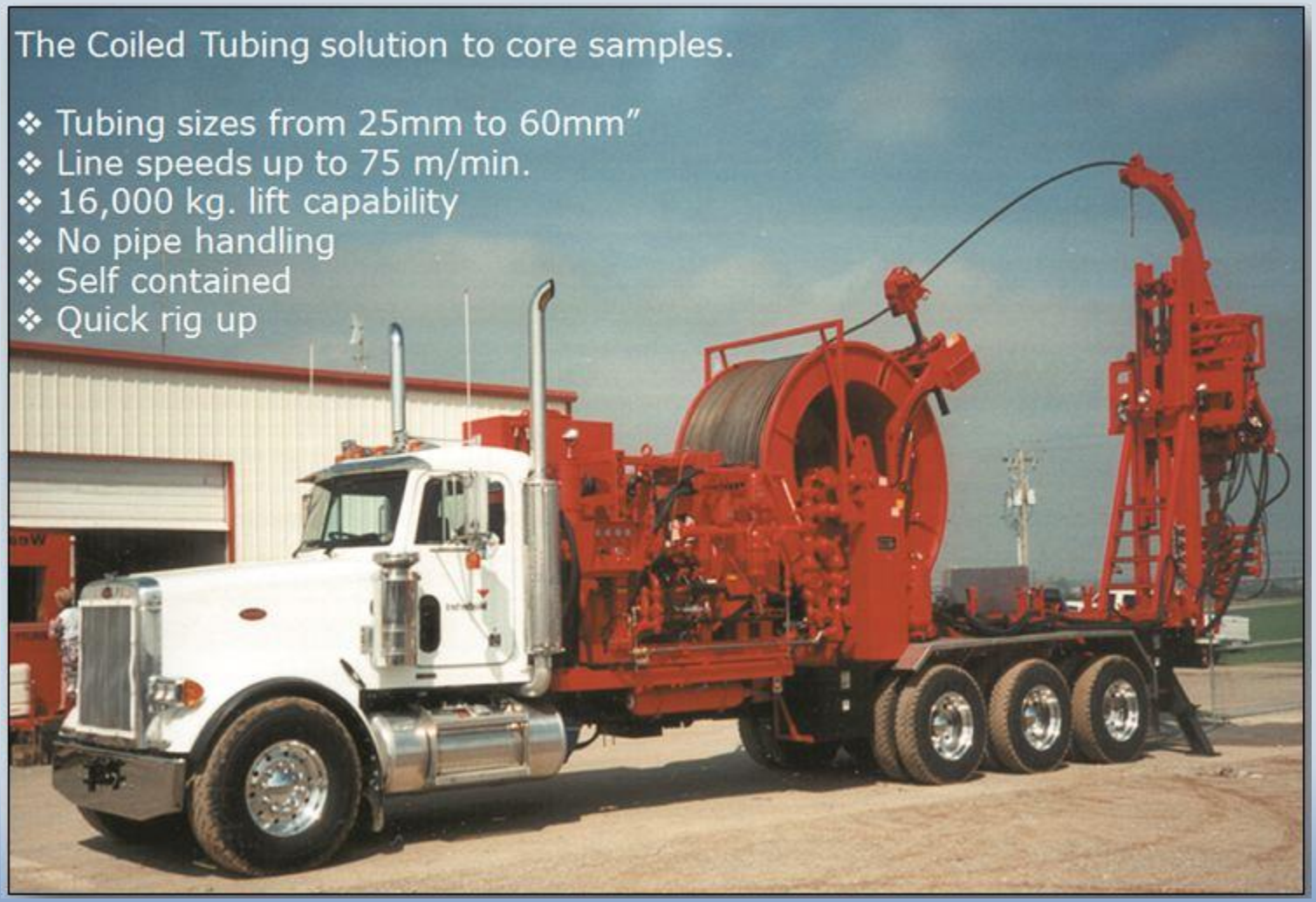
Where we are today – setting expectations





Ref.: Mineral prospectivity mapping2 (MPM) project GeoSurveyFinland: http://newprojects.gtk.fi/mpm/

DET-CRC



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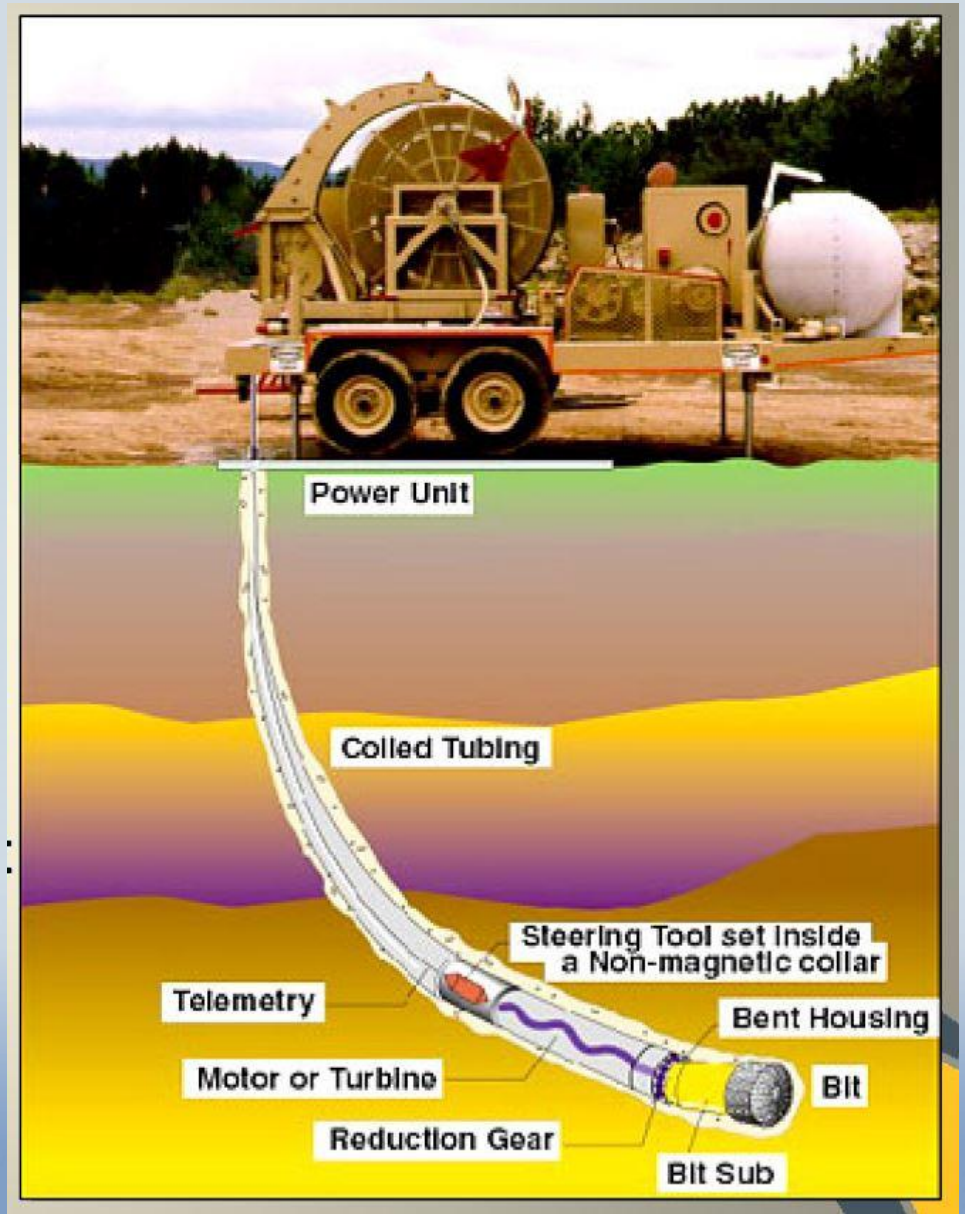
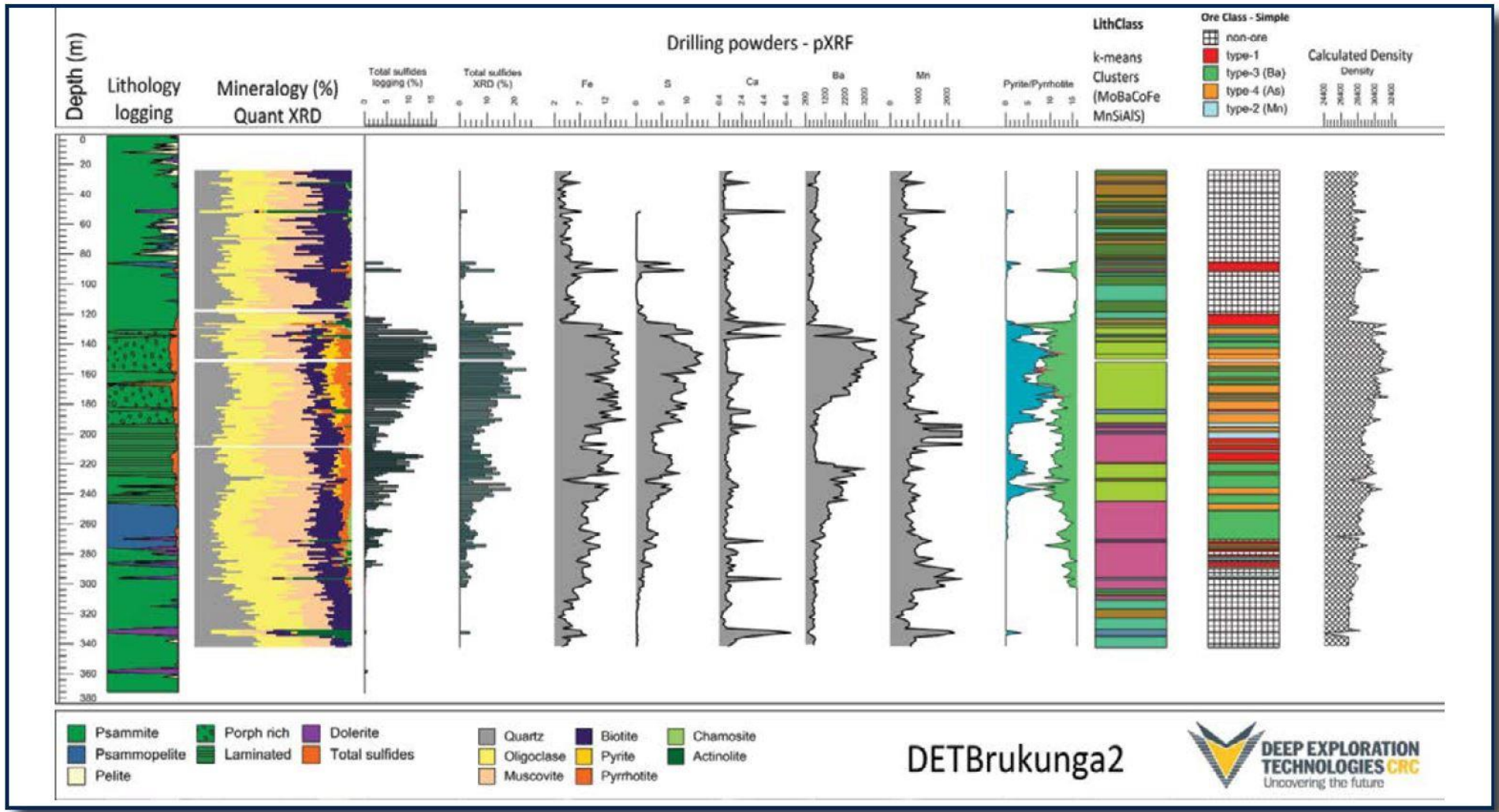
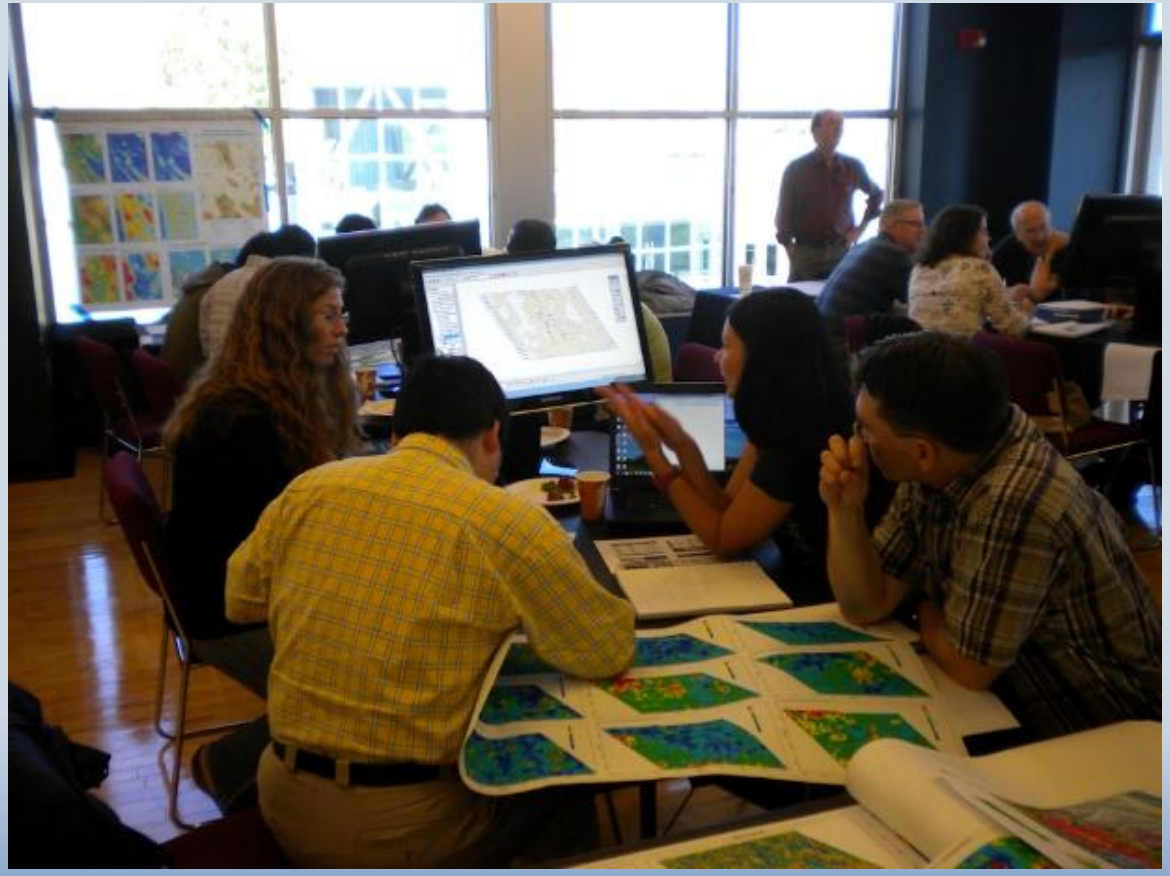


DET-CRC
Lab-at-Rig



People in the Loop



People in the Loop

Mining Journal

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Must-read articles from our 'Mining Disrupted' series

The $2 trillion global mining industry has been the focus of ‘disruption’ talk for some time. Internally, leaders have suggested the “industry won’t look the same in 10 years”. **But will it take an outside disruptor to truly turn the business of mining upside down?**

Acknowledgments

- To the “many” who offered up 2,500 years of advice!
- Graham Closs-CSM Emeritus
- Leigh Freeman
- Paul Bartos