Aerial Survey, Earth Sciences and Africa's 21st Century

Valedictory address

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Thursday 3 March 2005
Enschede, The Netherlands

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ISBN 90 6164 232 9

Introduction

In 2002 Exploration Geophysics in ITC became an 'expiring chair'. If there is anyone who came simply to watch me expire, then I hope they will be disappointed! Forty minutes is, in any case, a generous allowance for a last breath.

I have chosen for my title 'Aerial Survey, Earth Sciences and Africa's 21st Century'. This deserves some explanation. When, in 1982, ITC advertised a chair in exploration geophysics with an emphasis on airborne survey methods it showed a degree of relevance and enlightenment in the affairs of the developing world that merited my close attention. I set out the ambitions I had to match the honour of my appointment in my inaugural address (Reeves, 1984). As things turned out, it also provided, for the next 20 years - half a career - a vehicle for my professional enthusiasm and a catalogue of activities that the world can evaluate. It is in the nature of things that times change and now is clearly a good time to move on. Neither the 'aerial survey' nor the 'earth sciences' are any longer items the institute chooses to advertise in its title. We have not yet solved the problems of Africa, however, and this is what I want to address in some detail today. This is timely because there are many initiatives in 2005 to address the problems of Africa, such as the G7, the G8 and the Make Poverty History campaign. 'Africa is a place plagued with problems … so embedded and widespread that no continent, no matter how rich, could tackle them on its own. And Africa is not rich.' (Blair, 2005).

But let me start at the beginning.

When I was very small, I struggled to understand a conundrum. As a family we were not rich and times were tough in post-war Britain. But after a while we had an old car and even, eventually, a television set. As I built up an awareness of the wider world in which I found myself, I enjoyed finding my older sister's national geographic magazines and looking through them, probably even before I could read the words. In Africa, I noticed, the children appeared to have much less than I did. Most of them appeared not even to have clothes. What sort of world was it where I had clothes and they did not? Why was I the lucky one?

Decades later, I found a quotation from the infamous Cecil Rhodes that summarises this rather neatly:

'*To be born British is to win first prize in the lottery of life.*'

I hope that you, like me, find this shamefully lacking in political correctness. But the awful truth is that **the average person in Africa was better off financially when I was a child than he or she is now, 50 years later - by a factor of two!**

Africa in need

Africa is 22 per cent of the world's land area, is home to 12 per cent of the world's population, yet generates and consumes only 2 per cent of the world's electricity and attracts less than 1 per cent of the world's foreign investment. From an economic point of view, if it ceased to exist, most people would hardly notice. The media, however, remind us of a menu of civil war, famine and deprivation that pricks us into action or at least awakens our conscience. 49 per cent of Africans live on less than one dollar a day; 1 in 3 is undernourished and 28 million suffer from HIV/Aids. Deaths from and war preventable diseases in Africa amount to an Asian tsunami every few weeks. And the continent contains some truly majestic unspoilt places that need preserving from the ravages of farmers, foresters and poachers if they are to remain for future generations to see and appreciate.

Poverty, particularly desperate poverty, is probably the greatest enemy of the environment. Who can blame anyone desperate to feed a family for actions that are environmentally unfriendly? And proper care of the environment is a luxury that even some of the world's richest nations seem reluctant to afford. Everything we cannot grow is ultimately 'borrowed' from the earth - and it gets returned either as carbon dioxide or in pretty poor shape such as dirty water, toxic waste and so forth. This is not the topic for today, however. Environmental care costs the money that there is never enough of. How can we generate the wealth that will be necessary to give better standards of living to those most desperately in need?

A solution for poverty - the lesson of Botswana

When I first went to Africa in 1969 to work for the Geological Survey of Botswana, that country was the fourth poorest country in the world. Many people wore rags and the entire national telephone directory was the size of a very small school exercise book. Even four years after independence, the first piece of government stationery I saw was grandly headed with 'Bechuanaland Protectorate' - crossed out and 'Botswana' written in in blue crayon. In the 35 years since then it has become the richest country per capita on the continent and a rare African success story. At independence (1966) there were no secondary schools, only *mission* hospitals and less than 20 km of tar road in the entire country, the size of France (Young, 1966). Now they have the schools, hospitals and roads that they need. This is the difference that real, rapid development can make. Not that they have solved all their problems, of course, but at least they have the luxury of some national wealth with which to ***tackle*** the new ones. I am able to give you some human dimension to this because, a few years ago, I was invited back to help celebrate the Geological Survey's 50th anniversary. Here, resplendent in retirement, are some of the field hands I had worked with during long months in the Kalahari in the early 1970s. More important, their children were making sound progress and substantial careers after a good education.

The source of Botswana's wealth, in a word, is diamonds. The credit for finding and developing the diamonds must go to De Beers, but the national economic success must be credited to the Botswana Government for its wise handling of the politics and economics. In turn, credit should go to the Geological Survey of Botswana for maintaining the national geoscience data infrastructure that made - and continues to make - Botswana a good place to explore. And invest.

As the Geological Survey's first geophysicist, it was an important part of my own professional education to discover, after the first week or so on the job, that I had exhausted the supply of background reading on the geology of Botswana. I can tell you that, when your main problem is lack of data - or geo-ignorance, let me call it - geoinformation management doesn't rank very highly as a potential occupation. Very simple geological questions that I directed at

long-serving geologists all seemed to meet the same routine answer: "We don't know". A large part of this ignorance was due to the fact that 70 per cent of the country is covered with the Kalahari Sand that totally obscures the solid geology. Eventually, John Hepworth, survey director for most of my five years in Botswana, came with a better answer: "You're our geophysicist. It's your job to go and find out!" As a result, the first national gravity coverage of the country was carried out and, soon after, Canadian government financial support was secured for the first aeromagnetic survey. A good impression of the 'derring-do' style of getting things done in the field at this time is given by Chris Scholz in his book, *Fieldwork* (Scholz, 1997).

The greatest compliment that has been paid to the importance of these early, 'amateur' surveys is that they have all been replaced by modern, professional coverage to the highest standards in more recent years. Once the value of regional geophysical coverage to geological reconnaissance is realized, it is a very small step further to realize that only the technologically most sophisticated coverage is good enough. And that coverage should be repeated as the survey technology improves.

Canada, Australia, Africa

All the projects I have undertaken in the 30 years since I left Botswana have been variations on this same theme. I can't mention them all today and I have been very fortunate that my students have taken me - in their research projects, if not in the flesh - to many different countries. But I cannot miss mentioning the reinforcement my ideas I received during the two years I spent in Australia, 1991-3, on special leave from ITC. Geophysical mapping from the air has been high on the agenda in Australia since the federal geological survey was founded as the Bureau of Mineral Resources in 1946. The first magnetic anomaly image of the whole of Australia appeared from my group there in 1993 and has already gone into its fourth edition. Through modern web-access, it has become one of the foundations of the continent's excellent geological information infrastructure *(www.ga.gov.au)*.

I had already learnt the importance of aeromagnetic coverage to the mapping of whole continents during my time in Canada, 1976-83. Canada first set the pace for systematic geophysical mapping of their territory - a little, but not much, larger than Australia - in the 1950s and 1960s. What is not coincidental, I am sure, is that it is now from Canada and Australia, the two 'giant' countries in terms of solid-mineral investment worldwide, that 80 per cent of the current investment capital in Africa's mineral potential comes. Even so, you should remember that Africa is almost twice the size of Australia and Canada *combined* but still attracts less than half the investment in mineral exploration. In other words, only about a quarter as much per square kilometer as the wide open spaces of Canada's tundra and Australia's outback (see Figure 1; ASEG, 2004). Even this is far better than Dijkstra reported in his valedictory address in 1990 (Dijkstra, 1990). In this sense Africa has benefited from globalisation in the last fifteen years. But Africa has ten times the population of Canada plus Australia and there is clearly still room for improvement.

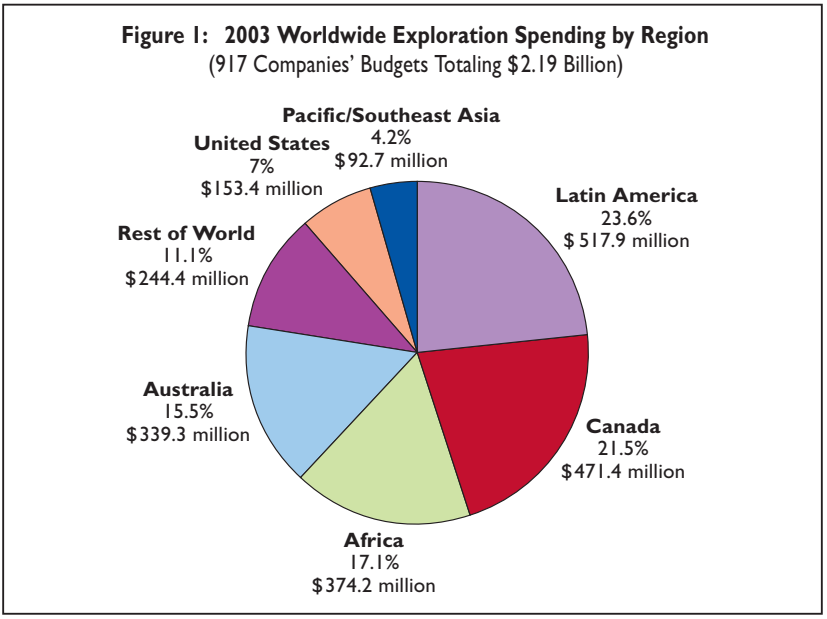

Figure 1. *Africa's share of the pie - 1 (ASEG, 2004)*

There is obviously an opportunity. Why is it not being taken up faster? Ten years ago I remember hearing a hard-nosed businessman in minerals comparing Africa and Siberia as places to invest. Trying his best to be positive, Siberia, he said, has the well-trained work force and the efficient infrastructure. Africa has the nice climate.

Objectively, three items determine the attractiveness of any country for mineral investment, given that the geology of Africa is no less attractive than that of, say, Canada or Australia:

1. Political stability and good governance.
2. Fair mining legislation and fiscal regime.
3. A good geoscience data infrastructure.

The first two items are - however worthy - beyond the scope of the professional earth scientist, except perhaps in a valedictory address! In this sense, politics and diplomacy have a much greater role than earth science in determining Africa's future, as Robert Cooper would, I am sure, agree (Cooper, 2004). 'Finding ways to get badly governed countries to raise their game is, to say the least, notoriously hard (and hugely controversial) for outsiders to do' (The Economist, 2004).

But the geoscience database - or the lack of geo-ignorance - is something that we as scientists should certainly be concerned with. And, having established the importance of aeromagnetic coverage, it is only natural that those looking for worthwhile geoinformation in new territories in Africa pretty soon ask the question: "What is the aeromagnetic coverage like? How easily can I get it?"

The AMMP contribution and its follow-up

In fact, we asked this same question in the 1980s at ITC and eventually, in cooperation with our geophysical colleagues at the University of Leeds in England and at Paterson, Grant and Watson in Toronto, we persuaded sponsors to come up with the US$ 4 million cost of cataloguing, retrieving, digitizing and compiling almost 1000 separate surveys carried out over Africa since about 1950 - AMMP, the African Magnetic Mapping Project! (Barritt, 1993).

This catalogue is in need of updating because much new survey coverage has been made in the past 13 years - but mostly in the countries where the importance of this had been established by what we might now call 'first generation' surveys. However, what is still outstanding from first impressions given by this map, is that (1) large areas of Africa remain to be covered, (2) many large areas are covered only with 1960s-70s surveys of technically low specifications that do not offer the resolution possible with modern techniques and (3) other areas are covered by surveys that remain inaccessible to general users, even decades after being carried out. Data ownership is still a major obstacle to good science, particularly where commercial interests or national security are perceived to be at stake.

Aeromagnetic survey, as we have seen, is the modern precursor to geological mapping. Primary geological mapping has always been in the forefront of initiatives to understand the resource base and inventorise its potential - and hence high on the agenda of national geological survey activities. However, even at the reconnaissance scale of 1:250 000, the task of geological mapping is far from complete. In Africa it is thought that less than half the continent has yet been mapped at 1:250 000 scale and that only half the map sheets that have been surveyed have actually been published (Reedman *et al.*, 1998). No basic geological information is therefore available at even reconnaissance scale for three-quarters of the continent - even if you take the trouble to travel to the country of interest in search of the paper maps. In Australia, by contrast, the first pass at this task was completed between about 1948 and 1980. So, while there is certainly more aeromagnetic coverage than geological map coverage in Africa, both items are sadly in need of attention. And, to paraphrase the original concept of where ITC can contribute to international development - 'No development without maps'.

If we think about *digital* information on geology, the impact of this revolution is certainly still in the future, but probably not by much. With an eye to its global resource needs, the US has been taking the lead so far, as well as setting a precedent by making the digital data available free of charge. At present the best available USGS digital geology of Africa contains only about one sixth of the megabytes of the similar coverage of the much smaller area of Saudi Arabia, for example. I find it a cause of some current concern that the second

significant player in this league and one of the most respected and scientifically logical forces in global geology for decades - Unesco - has recently decided to abandon much of its basic earth science activity, potentially delivering another victory for geo-ignorance!

But I digress. The point is that many large parts of Africa are, even now, no better off in terms of useful and reliable basic geoscience information than Botswana was 35 years ago. However, the opportunity to repeat elsewhere what has happened in Botswana seems very appealing if, as many politicians seems to think (e.g. Blair, 2005), the time is ripe to make bigger efforts to solve Africa's poverty problems by 2015, or at least in the current century.

African Oil

Let us not concern ourselves only with minerals. While various commentators make different predictions as to what the present century will bring for mankind, it is certain that the world will want oil and gas for at least the next 50. It is also certain that it will eventually run out - we are consuming these resources about one million times faster than nature was able to create them (KNAW, 2004). If anyone doubts the importance of motorised transport in the years ahead, they can leave me their car keys when they go home today, or better still, their air tickets for their next holiday. What diamonds did for Botswana, can oil (instead of, or as well as, solid minerals) do for other places in Africa?

Nigeria has long been the main source of oil in sub-Saharan Africa. It has more recently been joined by other countries such as Angola and Gabon. And what the oil industry can do in terms of - particularly offshore - technology for exploration and production makes rocket science look pretty simple. As exploration moves into deeper waters, the resources of Africa's Atlantic coast promise a new resource bonanza. Angola already satisfies 8 per cent of the United States' enormous thirst for crude oil.

Two new pieces of oil infrastructure in Africa's interior call attention to themselves, namely the pipelines from southern Sudan to the Red Sea, and

that from Chad to the Atlantic coast in Cameroon. While it takes proven reserves to justify such enormous investments, the pipelines both have excess capacity, so finding and developing neighbouring fields has become very attractive. Geologically, the rift structure hosting the oil is a relic of the time South America broke away from Africa, threatening to fracture the whole continent in the process. It is tens of times bigger than the oil-bearing province of the North Sea. In Sudan, one concession area alone is as big as the Netherlands! It is unlikely that what has been found so far is all, or even the best, of what waits to be discovered. Exploration of Africa's east coast, meanwhile, is only now beginning to get started.

So oil revenues for at least some parts of Africa can be virtually guaranteed, provided the diplomatic and political climate can be kept favourable. But oil often brings troubles, creates motives to awaken old hostilities in the sharing of the revenues. The over-simple reaction of the West in Africa (unlike elsewhere) is often simply to leave well alone. For example, there is no longer any western involvement in Sudan's oil patch. It was driven away by public opinion in the West. Sudan now supplies 10 per cent of China's growing thirst for imported oil, a trend that will undoubtedly continue. A much better alternative is for the western countries to remain engaged and strive for a socially responsible outcome and a formula to ensure societal benefits in the countries collecting the revenues. Former Dutch development minister Herfkens argued strongly to maintain this involvement during her time in office. British Prime Minister Blair argues similarly in his article in The Economist as recently as January this year.

Most people, when they think of oil, think of the big western oil companies and perhaps think that they have a capitalistic monopoly on the world's oil resources. In actual fact, nothing could be further from the truth (KNAW, Dec. 2004). 70 per cent of the world's oil is in the hands of national oil monopolies owned by governments keen on balancing their national budgets and, in some cases, largely immune to the pressure of shareholders and consumers that at least try to ensure responsible corporate behaviour in the democracies of the west.

An African development model

Prediction, it is said, is difficult, particularly when it involves the future. But what may the future hold for Africa? Africa's 22 per cent of the world's land area is certainly not going to remain unexplored, if only because it contains - probably - 22 per cent of the resources that the world needs. And the world's needs will increase as development in China and India (for example) takes off in a globalised world. What needs to be ensured is that the *people* of Africa get their share of the resulting revenue so that, 50 years from now, they have the basic infrastructure that can ensure a standard of living that compares more favourably with the rest of the world. Putting aside the politics and the economics for a while, what can earth science contribute to this?

If the development of Africa's resources is more-or-less inevitable, the strategy, as I see it, should be to ensure a maximum of African involvement in the process. Without this we head towards a new style of economic colonialisation that is not so different from what Rhodes would recognize over a hundred years ago. The globalised world does not need *African* scientists and engineers - it can get such specialists from wherever in the world they cost least. But **Africa** needs African scientists and engineers to play their role in this future scenario. How else can a country secure its rightful place at the negotiating table when these exploration and resource development projects are being planned? So it is exactly here that I would place ITC's role in the earth sciences - helping provide Africa with a robust geoscience infrastructure that includes well-trained indigenous specialists. And is it here that I would also hope that the Netherlands aid policy would see advantages for investment. Making opportunities for intelligent, dynamic young people to see a future in their own countries is clearly an objective that will, eventually, solve many global problems. And Dutch generosity in offering opportunities to students is one that is matched by too few other countries in the western world, whatever the cartoonist may say (Figure 2).

Figure 2. *Africa's share of the pie - 2. (Haagsche Courant, 22 Sept. 2000)*

What to do next?

I hope I have stressed sufficiently the need to upgrade the geoscience infrastructure of Africa, and I am sure that this path will gradually be taken up. But now I want to say something about my optimism for GIS applications as a catalyst for this.

It is clear to me that, even with good progress, African geoscience data coverages will not be complete for years to come. In fact, it is probably logical to think that coverages will *never* be complete. It seems axiomatic in every earth science project that the data is always short of the ideal that one would wish for. But earth scientists are familiar with the problem of 'playing with less than a full deck'. And earth scientists can come to profound new understanding

of the geology and structure of an area with less than a full data set. 'Discovery consists of seeing what everyone else has seen and thinking what no-one else has thought' (Albert Szent-Gyorgi). This is the power of science to make general conclusions - or at least working hypotheses - without first making every conceivable experiment. That is why I think it is very important to moblise the resources of GIS to assemble what we already know of the geology of the whole of Africa. In this way scientists can use this information to try and understand the processes at work and ask the right questions. Only then can the next costly acquisition of data can be targeted on the key areas where the model can be tested most effectively.

But we must work at a continental scale. This cannot be done without proper integration of geological, geophysical and other data from many diverse sources. There are, for example, more than 50 national geological surveys in Africa. It is here particularly that I see GIS as a new tool that can function as a scientific work-bench to assemble and understand better (and *distribute*) what we already know and so bring new summative knowledge and understanding to African geology. Not least, we should use GIS as a method of teaching what we know and don't know of earth science to a new generation of African scientists - not to mention educating a new generation of manager-sceptics who may replace the past two generations whose legacy is mostly in reduced funding and perpetuation of geo-ignorance in Africa (Reeves, 2001, 2002).

One of my proudest achievements at ITC was the *Gondwana* project which attempted part of this understanding process for the southern continents, starting in 1995. The flagship of this work is the website animation that has now been seen by over 250 000 visitors and been adopted in universities and schools around the world as part of their teaching resources (kartoweb.itc.nl/gondwana). You have to see the new version… Needless to say, in my retirement I will seek time and support for renewed interest in this. The software from Alan Smith and Lawrence Rush in Cambridge is an important element.

There is a new initiative in South Africa to promote geophysical education and research in Africa called AfricaArray. I have been honoured by an invitation to take up a small part in this activity, the emphasis being on creating a network -

both of geophysical instrumentation and of educational resources - across a large part of the continent that, I am sure, embraces opportunities for much of what I have been talking about today.

On the global scene, the magnetic anomaly map of the world has yet to be drawn, though much of the data necessary to do so already exists. I am flattered to be part of the IAGA team that are charged with carrying this out.

There is a great deal to do. And, as I warned in my inaugural address over twenty years ago, we should not be distracted into doing something else simply because it is easier.

In summary

While humanitarian aid and direct poverty alleviation will remain necessary for some years to come, responsible development of Africa's oil, gas and mineral resources over the coming fifty years could play an important part in bankrolling development of a social infrastructure, commensurate with the need to generate higher standards of living among its people. Oxfam estimates that an increase of just one per cent in Africa's share of world exports would be equivalent to five times the value of all present aid contributions.

This scenario encompasses both the need for resources and the ability to pay for them in the rest of the world and Africa's ability to supply the goods.

Success in terms of Africa's part of the deal will depend on its responsible participation in these events at all levels, including with professional and scientific expertise to represent the positions and interests of the countries involved.

In terms of earth science, the globalised world does not need African earth scientists, but Africa *does* if it is to maintain this involvement and build - preferably ahead of time - the geoscience data infrastructure that is presently in such poor shape.

The database is needed not only for resource development but also for groundwater and environmental solutions as well, though these applications may never be able to afford their contribution on their own.

So, I am returning to a world that I am familiar with where I hope I can still make a useful contribution. But it fills me with sadness that I have somehow failed to bring ITC round to thinking about Africa and the world the way I have described them today.

Thanks

It has been a real privilege to have been a professor at ITC. Unfortunately, few of those good people who originally put their trust in me are still here to thank. But there are a lot of other people to whom I want to extend gratitude:

Little of what the Exploration Geophysics Division achieved would have happened without the Netherlands Fellowship Programme (NFP) supporting our supply of students. Somehow it should be recognised that the NFP has made an enormous contribution to educating practical geophysicists for the developing world through ITC. Exact numbers are hard to come by, but I have seen well over 200 postgraduate students since 1983 and there were easily a further 100 since the course started in 1965. Well over 50 geophysicists have graduated with MScs during my term and there were about a further 10 in the earlier years - when MScs were still little-known in ITC. Many of these have gone on to careers of rewarding work and professional distinction. Statistically, almost half of them came from Africa. It is sad - also for our many Delft alumni - to see the end of this specialised programme after nearly 40 years. For the first time in its 75 years existence, the Society of Exploration Geophysicists now claims that over half its 21 000-strong membership is living outside of the USA. Globalisation goes on apace, and the job of global education in practical geophysics is only just beginning to gain momentum. The NFP contributed greatly to making that start.

The students themselves deserve my thanks for putting their trust in us. Anyone giving up a year or more of their lives to higher studies needs to be assured that they are getting the best possible. I have always been very conscious of our obligations in this respect. We hear more and more about course content - but as far as professional training in applied geophysics is concerned this has meant death by a thousand cuts. Ultimately students need to learn only two things: To think for themselves and to question everything they are told. This is the expectation of university graduates everywhere. It is not just the duty of the professors.

Geophysics was only a part of what grew out of the so-called 'mining' courses in Delft. Founding and nurturing this part of ITC's portfolio is largely to the credit of the late Professors Otto Koefoed (TU Delft) and Sietze Dijkstra of ITC. Generous input from other Delft institutes and individuals was the hallmark of the 1980s. Frequent meetings with leaders from our sister organizations punctuated our activities and we shared in many aspects of logistic support. At the risk of offending the others, I would personally single out Anton Ziolkowski and Jacob Fokkema for their time-consuming support as chairmen of our MSc examination boards and the assurance they provided, even into the more competitive years of the 1990s, that there were no short cuts in the academic quality of ITC's geophysics MSc degrees.

From this period I would also like to mention the support of Klaas Jan Beek as Rector of ITC. With hindsight we can see a golden age with the recruitment of a truly international cast of ITC professors, each with a role to play.

Whatever ITC has achieved in exploration geophysics was not done without a strong core of geophysical staff. This took a while to establish in my early years but did become very stable. The group of five that I will always remember as my 'ITC geophysical colleagues' now have over 100 years of ITC service between them, but the clock has now stopped ticking for most of us. In order of service length: Wim Hugens, Rob Sporry (who joined in 1983, the day I did), Sally Barritt and Jean Roy. I should also mention Peter Zeil who, as a precursor to Jean, brought us up to what I considered a minimum sustainable geophysical staff number of five in 1988. I have never for a moment needed to question the devotedness of all these good people.

We always thought and worked as a team because we shared common goals. I feel that they all 'stood on their toes' far too long in the hope that better times lay ahead if only we showed sufficient hard work and success. Each of them has a catalogue of professional achievements that the proceedings of earlier today have demonstrated - but only in small part because they are all far too modest.

Our colleagues in Mineral Exploration, Engineering Geology and the supporting staff made up the whole close-knit ITC Delft family. Professional, practical, pro-active - it was the epitome of what ITC strives to be. I was proud to be part of that family and, like a family, it seemed to live for 24 hours every day. To those former colleagues who made the long journey here today, thank you for the support you always gave me.

This afternoon's earlier speakers represent a generation of contempories that I have been lucky to come into contact with and who are still busy making enormous contributions. Ian: ITC took me away from whatever my contribution to Geosoft might have been in its formative years, but it is elevating to see what it has become without me. For Professors Zhou and Murthy, ITC has proved a springboard for your talents and the contributions you are making to the futures of your own countries. Thank you, all three, for letting us share in your wisdom today, and good wishes for your continued success.

I approach the end. A word to everyone in Enschede who tried to make me feel welcome these last few years since ITC left Delft. I may not have been the best company following the crumbling of so many things I had worked hard for. I hope, following the example of Geosoft, that things in Enschede will go from strength to strength without me!

Absolutely finally, I want to mention my own family. When I joined ITC there was just my wife, Ann. It is the way of the world that numbers increase and it is wonderful for me that three more fully home-grown Delftenaren are with Ann in the audience today: Richard, Alexander and Suzanna. I hope you three find that being born in Delft is pretty fortunate, even if you haven't yet won any lottery! But for ITC, all four of you might have seen quite a lot of more of

me these last 20 years. Whatever I have done was only possible because you were all always there to come home to. I have certainly been very fortunate. Most of all, I hope that my children, like our students, will find professions and a career full of organizations where they can develop, feel at home and contribute through questioning the wisdom of what goes on.

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