1. INTRODUCTION

It’s apparent, when you look at the parallel evolution of geological organisations across at least 3 continents, that 3/4D modelling has progressed by leaps and bounds in the last 5 years. It appears to have come of age. The sophistication and range of the modelling software is impressive, the array of applications in a variety of economic and environmental sectors is extensive and the visualisation techniques can be breathtaking. There is no doubt the geoscience community should look at the move, from what is, essentially, an anachronistic 19th century paradigm of 2 dimensional maps and sections, to the full 4 dimensions that geology occupies in the real world, with a sense of achievement. But should we be satisfied? Is that it? Is there anything left to solve?

Most would agree that we have hardly (and forgive the pun) scratched the surface. From the perspective of those of us who work in Geological Surveys there is still an awful long way to go. The intention of this paper is to outline a few challenges that ought to keep us occupied for a couple of years yet. It is a paper with more questions than answers.

2. ANYONE CAN PICK CHERRIES

3D modelling software is plentiful, varied and inexpensive and it’s no longer too difficult to build a one-off 3D model for a particular research area. Without wishing to diminish these achievements and their individual innovative contribution, for a geological survey such projects are little more than pilot studies and demonstrations. To continue with such an approach alone is arguably no more than academic cherry picking. For organisations charged with a national, long term and strategic “mapping” remit, the serious and much more difficult challenge is to contemplate building and deploying robust operational modelling systems across whole organisations. To do that they must overcome a much greater (human) challenge; that of sensitively and positively changing the work patterns and culture of survey geologists.

3. WHAT RUNS THROUGH THE PIPES IS MORE IMPORTANT THAN THE PLUMBING

The acceleration in the versatility of software and the speed and capacity of hardware (sometimes referred to as the “plumbing”) cannot fail to impress. But what flows through the plumbing – the data content – is, arguably, more important. Regrettably, digital geoscience data content (its availability, quality and consistency) is far less mature than the plumbing. Digital content is the current limiter for Geological Surveys, not the sophistication of the hardware or applications. Lack of quality assured content severely restricts strategic and national initiatives. The burden of having to convert analogue data into digital form, then quality assure, condition and harmonise prior to a project, is a huge overhead for any venture, requiring a significant amount of often skilled human input. Yet with a more responsible approach in the past, an appreciation of the post-project value of data, respect for compliance with some basic rules and standards (as opposed to expedient and idiosyncratic wheel re-invention), we could all have been in a more favourable position today. Why hasn’t the geoscience community devoted more time to agreeing basic data models and dictionaries? Why have we rushed on to the next project, without properly storing and describing the data and models we have spent so much time producing; reducing the sustainability, re-use and potential added value of our work at a stroke? This message is far from new, but how many of us can say that we/our organisations are not continuing to make the same mistake today and how many Surveys have (and are enforcing) data policies that would deal with the problem?

4. MODELLING IS A WAY OF LIFE NOT AN ISOLATED COMPONENT

Getting serious and professional about 3D modelling means embracing it throughout the geological data lifecycle. To achieve the synergies, efficiencies and benefits an organisation should be thinking 3/4D modelling at the inception of a project, building it into fieldwork/data acquisition - most field geologists have a 3 dimensional model in their head when they are doing their mapping, isn’t that invaluable knowledge largely lost when they merely commit it to 2D maps and sections? The data processing and analysis stages should be designed with 3D in mind and we should ensure that dissemination and delivery take full advantage of
the potential of the third and fourth dimensions. Last but certainly not least, integrating within this system a means of storing the models for subsequent re-use is paramount. To allow any of these stages to be restricted to the limitations of the 2D paradigm would be retrograde.

5. **DO WE NEED TO GET OUT MORE? THE NOT-INVENTED-HERE SYNDROME**

We constantly tell government and those who review and audit us that Geological Surveys are unique centres of multidisciplinary geoscience – can we put our hands on our hearts and say we really operate that way? Do the geological, geophysical, geochemical, hydrogeological, and geotechnical “divisions” (the word is, literally, appropriate) of Surveys truly regard integration as a priority? At another level, we know that geology has no respect for political boundaries and that the environmental problems we face need an international approach, so why do we continue to operate in our own national silos, with little attention paid to the digital and taxonomic standards that would allow sharing of knowledge within and beyond our frontiers and the geological domain. Rather than dismissively looking down our noses at them, shouldn’t we recognise the enormous strides that are being made in the “geography-led” spatial data infrastructure (SDI) arena and be a strong part of it. Shouldn’t we borrow what we can from the other spatial and environmental sciences, some of which are much further advanced in taxonomy and semantics and mathematical modelling? And let’s not forget that sciences and technology, which at first sight might not seem to have much in common, e.g. medical scanning, pattern recognition may, in this mutual digital world, have a lot to offer. Finally, having enjoyed a decade or more of the initial graphic and glitzy attraction of modelling and GIS, isn’t it time we paid more attention to the maths that underpin it and our applications? How many of us include in our teams the oft-forgotten geostatisticians and mathematical modellers, people whose skills could enhance the scientific rigour of our work and open up new scientific discoveries?

6. **WHY X + Y + Z ≠ ☺**

We are continually asserting how relevant geology is to society and government and yet we know that a very small proportion of the population can interpret a geological map or model (estimated at a lot less than 0.5%). Do we really give enough attention and resource to communicating this relevant science to the public in a way that is meaningful and useful to them? A 3/4D model may seem a far more superior way to convey understanding of the spatial and temporal arrangement of the subsurface within the geoscience community. Unfortunately, while a model should definitely improve the wow factor, it may not always aid the comprehension of the issue by those outside that community. Complex and esoteric stratigraphy or physical properties remain complex and esoteric whether they are portrayed in 2 or 3 or 4 dimensions. We need to convey the messages in that model in a language the intended user will understand, be they a civil engineer, a government planner, or an insurance company. 3/4D modelling, together with virtualisation and visualisation, offer wonderful opportunities to make clear the societal implications of our work, but we lose a significant amount of their potential if we only communicate in the language of geoscience and forget the language of the client.

7. **JUST HOW CONFIDENT ARE WE?**

Delivering a model that people understand is a significant step, but we mustn’t stop there. The next step is something that we never really tackled in 2 dimensional mapping – the step to assess and describe our confidence in the model, its geometry and attributes. Geology is an interpretive science; there are often few geological “facts” and a great deal of interpretation, usually proportionate to the distance from ground surface. Most people outside the profession (including many engineers and surveyors) do not appreciate or understand this aspect of our science, the fact that it is more akin to a detective with a set of clues than an observed and measured structure. How can we best evaluate and then show our estimate of error in a way that is both reliable and meaningful? How do we best communicate the certainty/uncertainty of our predictions?

8. **THE WORLD DOESN’T OWE US A LIVING**

If Geological Surveys want to survive then they need to stay fresh and agile and responsive. They cannot afford to be complacent. Just because some of us have been doing what we do for 170 years does not give us a God-given right to do it for perpetuity. There is a limit to how often you can sell the geological re-mapping of a state or country and the move to systematic and operational modelling may provide a timely renaissance opportunity for some Surveys; but even this is not an absolute guarantee of survival. The digital advances that have presented us with such wonderful opportunities also (at least from the standpoint of a geological survey) now present some threats. Analogue methods coupled with government policy that has
been strongly protective of the public sector provision throughout most of the 19th and 20th centuries may have afforded us a very secure situation in the past. It does not take much imagination to see that novel computing solutions and ever richer digital geoscience data, coupled with governments seeking to reduce public expenditure and place more work in the private sector, threatens this privileged position. As a senior Google person said recently, when addressing an audience of the directors of the National Mapping Organisations of the world, “we’d love to work with you guys … but please do bear in mind that we don’t have to.”

9. **SO WHAT’S NEXT?**

Having used a large slice of this paper to advocate what is essentially a policy of “consolidate and deploy”, something that could be accused of being unambitious, let me be contrary. In a sense 3 and 4D modelling is yesterday’s news. As research geoscientists we can’t live on this forever. Where is the next great step change in geoscience information? In the 1980’s it was GIS, in the 1990’s it was 3 and 4D modelling; what is the next leap going to be? In addition to developments in visualisation and virtualisation, which technologies will impact on our science? How will the advancement of ontologies and the semantic web, and in particular image and graphic semantics, change our approach? What are the implications of ambient computing and the sensor web?

In a world that is changing and innovating, and in a sense shrinking, at an accelerating rate, one thing seems obvious – it would not be a wise strategy for any Geological Survey to assume it can operate in isolation.