THE EXCITEMENT OF SCIENCE DISCOVERIES IN THE BLUE SKY

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The articles in this "Comets" issue of *Elements* provide a fascinating account of comets and the making of our planetary system. We learn why comets are visible to the naked eye and about their complex organic geochemistry, the surprising find of free O_2, and the likelihood of a comet impact on Earth. Perhaps most impressively, we learn about the tremendous effort that goes into the exploration of comets. These missions require decades of design, planning, and instrument miniaturization and their culmination captures our imagination in a way little else can. Who could not be enthralled by the evocatively named *Stardust* mission returning a few thousand grains of dust from comet Wild 2 to Earth? We collectively shared the despair when communication was lost from *Rosetta*'s *Philae* lander on comet 67P/Churyumov–Gerasimenko, and the excitement about the unparalleled wealth of information sent back during its 70 hours of life on the comet's surface.

Clearly, all of this excitement comes at a cost. NASA classes "small" missions as those that cost around $500 million, whereas "large" missions – like the Mars landers – run into the billions of dollars. The Extremely Large Telescope being built by the European Southern Observatory in Chile will cost around €1 billion. Governments and funding agencies are obviously willing to pay these bills, even though mission statements of most funding agencies include addressing societal challenges as among their highest priorities. For example, the Helmholtz Association of German Research Centres, where I work, "contributes to solving the major challenges facing society, science and the economy"; the European Union's Horizon 2020 program places its emphasis on "excellent science, industrial leadership and tackling societal challenges"; and the new 2018 US National Science Foundation strategic plan identifies two objectives, one of which is "to promote the progress of science" and the other is "to advance the national health, prosperity, and welfare; to secure the national defense [!]; and for other purposes." Reading these mission statements closely, a tension emerges between the need to address societal challenges and a desire to promote so-called blue-sky research, i.e. curiosity-driven science for which the applications are not immediately apparent.

As geoscientists, we are familiar with the tension between these two strategic goals. We increasingly need to justify our research by its societal relevance perhaps more so than the "classic" science disciplines. The point here is not to bemoan or belittle geoscientists' responsibilities. Doubtlessly, we have a very major role to play in the grand challenges facing humanity. Combatting climate change, securing the supply of freshwater and rock-derived nutrients to nourish growing populations, guaranteeing a lasting supply of energy and mineral resources, or building resilience against natural hazards, all of which demand our contributions. However, do we really need to stretch the societal relevance of even the most basic research? For example, all (paleo-)climate research can relate in some way to global warming; mineralogical research to material development; and almost any geodynamic, volcanic, or petrologic research can be recast to address either "hazards" or "resources" challenges. A better justification strategy is to emphasize spin-off effects emerging from curiosity-driven research: advancing instrument development, discovering new technologies, transferring knowledge into other fields, or simply educating the scientific workforce needed in a technology-based society.

But isn't the most powerful justification for curiosity-driven research simply that the geosciences encompass some of the most exciting basic science questions, as exciting as the comet research in this issue of *Elements*? After all, much of the geosciences addresses our inherent human urge to understand our origins, the evolution of the planet we live on, the Earth-system stability that makes our planet habitable, and whether we are alone in the universe. So, while there is excellent geoscience research that directly benefits our societies and economies, we should also not shy away from communicating the fascination of blue-skies research as an equally worthy justification! But are we, as geoscientists, too reluctant or too modest to champion the fundamental science that we do? If our colleagues in planetary science can successfully advocate for costly interplanetary missions, why can't we geoscientists be similarly vociferous advocates for "big" curiosity-driven Earth science questions?

We can make this voice heard, for one, by continuing to argue for guaranteed funding schemes for curiosity-driven "small investigator" science – a cost-efficient means to ensure the flow of fresh ideas. We should, at the same time, increase our public science communication: make good use of our many enthusiastic and convincing (and young!) faces as communicators, and make more use of audio-visual tools. More broadly, we could learn much from the comet researchers: no one seriously questions the value of the *Rosetta* mission, although the benefits are hard to put into monetary terms. But what untold number of children have been inspired by the thought of landing a probe on a moving target after more than a decade racing though space – and then beaming back data about its composition? Imagine a similarly ambitious geoscience program! The benefits, beyond the unpredictable spin-offs, would include the geosciences attracting more of the brightest young minds who crave stimulation at the frontiers of science.

By conveying the excitement that fundamental geoscience research can trigger, we can help counter the flagging public faith in science. In the current climate, this may well be our most important contribution.

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