



## When the catfish awoke

An interview with Stephen Vaughan

On 11 March 2011, photographer [Stephen Vaughan](#) was standing at the base of the Tokyo Skytree – the world’s tallest tower. He had just packed up his camera when the ground started shaking. The buildings began to rattle. People became agitated. The Skytree swayed dramatically. “It took me some time to comprehend what was happening,” remembers Vaughan, “it was a strange, disturbing, and unforgettable sensation”.

Vaughan’s fascination with geological landscapes had begun many years previously, starting with a series of photographs of Iron Age human sacrifices, exquisitely preserved in northern European peat bogs. From there, his exploration of cultural histories and geological phenomena took him to Iceland – a landscape so alien that it was used by NASA astronauts for field training before their first moon landing. In 2009, Vaughan travelled to Japan to continue to make images at the interface between the cultural and the geological; he took photographs at natural locations – sites of geothermal activity and historical seismicity – that have been appropriated as spiritual

pilgrimages and tourist spectacles. He also visited the earthquake simulator at Japan’s [National Research Institute of Earth Science and Disaster Prevention](#). The resulting exhibition was called *The Catfish Sleeps* – a reference to the eighteenth century Japanese belief that the deity Kashima held a foundation stone on the head of a giant catfish to protect the population from the terrors of the earthquake when the catfish stirred.

Then, in 2011, Vaughan returned to Japan. His imagination had been sparked by a book called *The Orphan Tsunami*, by Brian Atwater and colleagues, which documents an unexplained tsunami on the northeast coast of Japan and its apparent links to the North American Cascadia earthquake of 1700. “My intention was to make a series of photographs in Iwate prefecture that acknowledged these invisible histories within the coastal landscape,” recalls Vaughan. “I had been researching historical seismic events and the probability of future earthquakes. So, for me, earthquakes were imagined but never experienced.”



Akahama, Otsuchi, Iwate Prefecture, Japan, 2011 (Credit: Stephen Vaughan)

It was then – whilst Vaughan was standing in central Tokyo – that the catfish awoke. The magnitude 9.0 Tohoku earthquake struck off the northeastern coast of Honshu and nearly 19,000 people died in the ensuing tsunami. Suddenly, the subject of Vaughan’s work became a visible reality. “I knew that I had to follow my original intentions by continuing the work I had planned to make,” explains Vaughan. As soon as it became possible, he travelled via the northwest coast of Honshu, then east to the city of Morioka, to those places in Iwate prefecture that had been devastated by the tsunami. He began to make photographs in Kuwagasaki, Tsugaruishi and Otsuchi. “Nothing had prepared me for the overwhelming scale of the disaster in these places,” says Vaughan, “The indiscriminate natural forces that created the total destruction that I saw are beyond my ability to comprehend or describe. But I also knew that I must make every effort to create a response to those events that was as accurate a description as I could possibly produce.”

In many ways, Vaughan’s presence in Japan at the time of the earthquake was the perfect opportunity to pursue his work, but he is also acutely aware of the human side of the catastrophe: “To make photographs within the context of such a disaster without questioning the validity of one’s own presence would be very problematic indeed. Parachuting into disaster zones to make images of other people’s suffering could be seen as exploitative and voyeuristic. I did not want to be associated with an unjustifiable intrusion of this kind.” But Vaughan certainly wasn’t an unjustified intruder. “I felt that my presence as an observer was validated by the wider context of my enquiry and the fact that I was personally involved and caught up in the events as a participant,” he explains.

“I felt a keen sense of responsibility to bear witness to what had happened there and to create a document that could contribute to an historical understanding of the disaster,” he says, “There was an inevitable tension between an urgency to engage with the subject before me, and the need to represent the subject with integrity and respect.” Vaughan’s overwhelming sense of this need for respect is indicative of his thoughtful and humble approach. After making his photographs, he spent a while volunteering in one of the evacuation centres.

The inherent tension that Vaughan feels in relation to his work is also something that continues as he has to decide how the images should be disseminated. His latest exhibition – *Tohoku*, which was

exhibited alongside *The Catfish Sleeps* at the 2012 EGU General Assembly – includes some remarkable works that bear witness to the scenes of destruction in minute detail. Reams of twisted debris dominate these landscapes and in the middle distance passenger ships are seen balanced atop people’s former homes. These busy images are made possible by Vaughan’s large-format camera – complete with darkcloth – and individual sheets of film. “I prefer to work slowly with the older technology,” he explains.

Vaughan is clearly fascinated by what is possible when photography and geology work in tandem; and nowhere is this more apparent than amongst the geological maps he uses to plan his expeditions. Prior to his work in Japan, he made practical use of a variety of maps – tectonic maps, volcanic maps, maps of historical seismicity and seismic rupture probability maps – to help decide which landscapes to photograph. “The journey that I made from the far north to the far south of Japan in 2009 included landscapes, cities and research facilities that relate directly to the accumulated information from those maps,” he explains. But for Vaughan the overlap between the arts and the sciences runs deeper than mere utility. “Many of the maps that I used in preparation for photographing in Japan are incredibly beautiful, graphic objects in their own right,” he says, “cartography and the visual arts both produce artifacts that require (or stimulate) complex readings. [Maps] act as shorthand to a more profound understanding of place and process. In this respect, they mirror the ambitions of art-making very closely indeed.”

It is Vaughan’s hope that his exhibition at the 2012 EGU General Assembly will allow him to continue this interdisciplinary work. “I am seeking ways to bring together my photographic work with physical and graphic artifacts from geoscientific research, and to discover new opportunities for projects in collaboration with geoscientists,” he says. And it seems that this sort of relationship could be a symbiotic one: Vaughan’s work requires geological knowledge and geology needs people like Vaughan to help explore new forms of geoscience communication for a wider public audience. Working together is clearly the way forward, but, as Vaughan already knows, both parties must be sensitive to the human aspect of disaster when the catfish next awakes.

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Otsuchi, Iwate Prefecture, Japan, 2011 (Credit: Stephen Vaughan)

# Landspotting: A new web tool to improve land cover validation

The rise of user generated media such as blogs, Twitter, Facebook, LinkedIn or Wikipedia, has bridged the gap that existed between the producers and consumers of information. With the advent of Internet technology, ordinary citizens with no scientific training in remote sensing can now contribute to society's overall knowledge base via crowdsourcing, whilst doing something they enjoy. Volunteered Geographic Information (VGI) refers explicitly to geospatial data that are created by participants with an interest in geography, cartography, biodiversity or related fields. Using GPS, mobile devices, photography, textual information or local knowledge, these volunteers are able to submit a variety of information to a website. This resource has already been used in the development of tools such as [Wikimapia](#), [Openstreetmap](#), [MapAction](#), and [Google Earth/Panoramio](#).

Tapping into the enormous potential that crowdsourcing and VGI have to offer, a team led by Steffen Fritz at the International Institute for Applied Systems Analysis in Austria, developed a [Geo-Wiki](#) in 2009. In Fritz' words, "Earth observation derived global land cover data products – for example [GLC-2000](#), [MODIS](#), and [GlobCover](#) – provide valuable information about land cover types, such as urban, forested, cropland, wetlands, shrubland, agriculture, conditions of natural resources, quality and quantity of water, snow and ice, etc. However, these land cover data products show a high degree of disagreement when compared with one another, and therefore a high degree of uncertainty in their estimates. The users of these data face many challenges, among other things due to cloud cover and misclassifications."

The Geo-Wiki application provides a web tool for volunteers. It was originally designed to solicit their feedback on whether the data provided by the three land cover types are correct, incorrect, or if the validator is unsure. The application has now moved towards asking volunteers to identify the land cover and other information, such

as the degree of human impact that is visible from Google Earth through competitions that are run on a regular basis. This allows users from around the globe to contribute to spatial land cover validation and classification via Google Earth. The application uses a predefined set of criteria to facilitate land cover validation; hence the VGI is more strictly referred to as F-VGI (Facilitated VGI). This package has a variety of research applications such as climate change, food security, monitoring of tropical deforestation, land use monitoring and modelling, etc. and it also allows users to create a validation sample for their own specific applications.

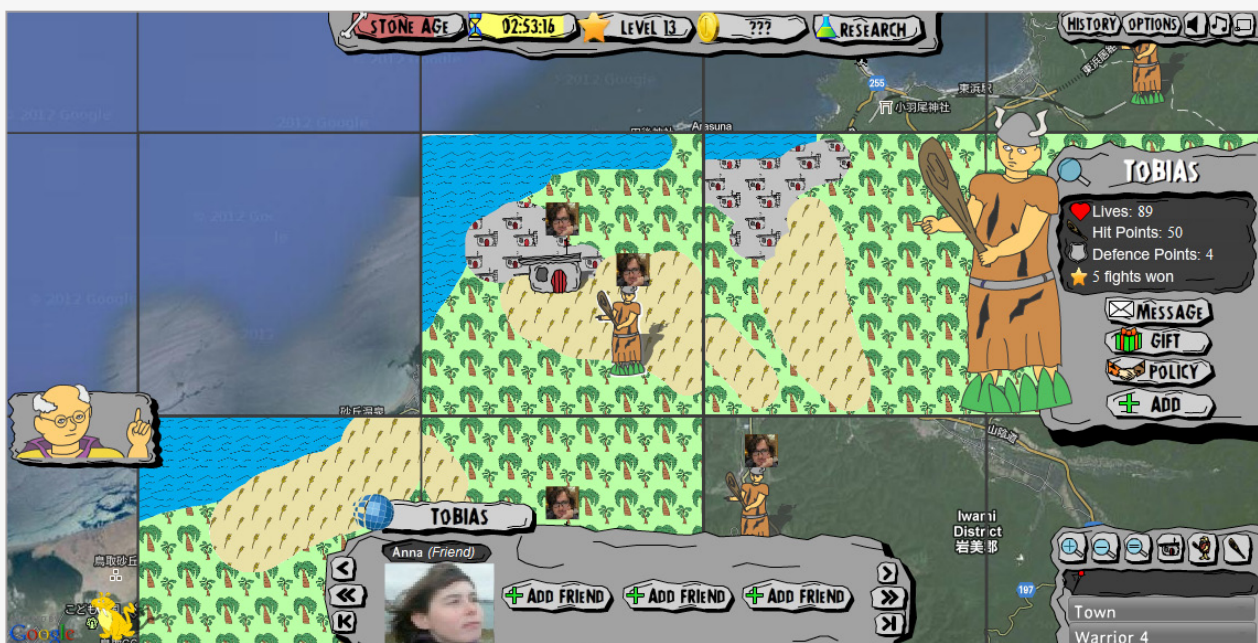
The Geo-Wiki team has now taken their development a step further by creating an innovative Landspotting game.

## The Landspotting project

With more than 600 million users around the world, Facebook has become a powerful social networking tool. Within Facebook there are games, such as [FarmVille](#), which encourage communication, social interaction, and the exchange of information. Crowdsourcing offers an enormous opportunity to engage people via 'serious gaming' on Facebook. [Foldit](#) is one such game, allowing players to collaborate and compete in predicting the structure of protein molecules.

Developed along similar lines, the Geo-Wiki team has recently launched their new [Landspotting game](#). This game aims to improve land cover data by engaging Internet users and game players in land cover validation exercises using Facebook.

"After a lot of brainstorming, we came up with the idea to develop a strategy game," says Tobias Sturn, the research at the Technical University of Vienna, Austria who built the Landspotting game.



A screenshot of the multiplayer game Landspotting: improving global land cover data via social gaming on Facebook.

Based on concepts similar to those used in the iconic strategy game [Civilization](#), players build (harvest, research, wage war, etc.) in a Stone Age world over thousands of years. Landspotting is similar to Civilization but it is played on Google Earth. The players are directed to certain hotspots of land cover uncertainty (information obtained from a comparison of the GLC-2000, MODIS, and GlobCover data sets), and are asked to enter or record the type of land cover they see. Using the 'Paint' tool, the players can map their territories, and classify Google Earth imagery into different land cover types.

"Motivating people to engage in playing games can sometimes be a tedious task. In order to encourage interaction whilst making it a global endeavour at the same time, we decided to provide rewards to incentivize the game," says Fritz.

The players score points for their entries. The game is particularly useful from a land cover perspective, since users are directed primarily to areas with high disagreement, and where high-resolution scenes are available for validation. In order to control for misuse, and improve the quality of the VGI, there is an overlap between the land cover validation pixels. The game is freely available to Facebook members and can be played anywhere using a web browser (where Flash is supported) without requiring the user to install additional software.

Since all users play the game on a single Google Earth map, the information regarding land cover is recorded and stored in a unique database along with uploaded photos. The data will eventually be used to create a more accurate, hybrid global land cover map that can be used in a number of crucial applications such as food security (especially in developing countries, where high quality datasets available are currently lacking), drought monitoring, forestry applications, carbon sequestration projects, and integrated assessment modelling.

## Validation competition

To increase participation, and to raise awareness among a greater number of people, the Geo-Wiki Team is inviting volunteers to participate in a validation competition. Each player is presented with pixels overlaid on Google Earth and is then asked to choose the land cover types up to a maximum of three classes including the percentage of the pixel that each type covers.

"The target is to collect more than 100,000 validation points that will provide valuable information for the future validation of land cover maps, and will also help us understand how much people have modified the landscape," says Fritz.

As an incentive, the top 10 classifiers will be invited to join as co-authors on a scientific publication that will be an extension to the 'human footprint' work done by [Sanderson et al. \(2002\)](#), and will be entitled: How much wilderness if there left on this planet? Furthermore, the top three classifiers will be awarded Amazon gift certificates of between 20 and 40 Euros.

Earning, learning, and contributing to a global endeavour by engaging in social gaming sounds like an exciting, and intriguing venture. For more information, visit: [competition.geo-wiki.org/](http://competition.geo-wiki.org/).

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A frame that shows the user exploring the land to enter/record the type of landcover they see while playing the Landspotting game.

# Life & times of granite

## How the igneous rock set the stage for the evolution of multicellular life

You may have learnt about life and evolution in a biology class at school, but geology also has a thing or two to say about the evolution of life on Earth. In fact, it can provide answers to some of biology's fundamental questions. Heavy metals, for example, including zinc, copper, and molybdenum, turn out to be exceptionally important for life, since certain proteins require them in their synthesis. Geology may hold the answer as to why life came to be so dependent on these metals: granites.

Or so claims a team of scientists led by John Parnell of the University of Aberdeen in Scotland, in [a recent study](#) published in *Geology*. The researchers suggest that, a couple of billion years ago, metal-rich magmas rose from the planet's interior to the near surface where they were deposited and cooled down to form granites. Weathering then freed up the metals in these rocks, which became available to primitive cells. The rest, as they say, is history.

The insight of Parnell and his collaborators was bringing biology and geology together. The development of sexual reproduction and the onset of the diversification of eukaryotes – organisms made up of nucleated cells – occurred in the Mesoproterozoic, the period in the Earth's history between 1.6 and one billion years ago. At about the same time, granites bearing metals known to have played a critical role in the evolution of complex cells became widely available.

"A lot of us in the community have noted loosely that there's this correlation and we've wondered if there's something to it," [said Ariel Anbar](#), a geologist at the Arizona State University in Tempe who did not take part in the study, to *Inside Science*.

Parnell and his collaborators believe there is. "We propose that metals were delivered [to primitive organisms at the Earth's surface] due to a critical combination of continental growth, near-surface metal concentration, and erosion into the surface environment during the Mesoproterozoic," they write in the paper.

The origin of sexual reproduction, a key event in life's history, was preceded by the formation of a supercontinent known as Nuna, or Columbia, some 1.9 billion years ago in the Palaeoproterozoic – the period just before the Mesoproterozoic. "This was a peak time of mantle-derived magmatism and hydrothermal activity perhaps unique in Earth's history," [Parnell said](#) to *New Scientist*. It was this continent-forming activity that delivered high concentrations of metals, trapped in the magma, from the mantle to just beneath the surface.

The molten material from within the Earth then cooled down and crystallized forming a particular variety of granite – one with a chemical composition that causes the metals to concentrate in ore deposits within, rather than distributed throughout, the rock.

These 'sulfide ore deposits' are readily eroded, and the authors cite a wealth of evidence in the geologic record suggesting this process started almost immediately after the granites formed. [Sedimentary records](#), for example, show that certain sulfate minerals



Granite boulders in La Digue, Seychelles (Image by S. Sollberger, distributed by EGU under a [Creative Commons licence](#))

were absent until about 1.7 to 1.6 billion years ago. The researchers believe their appearance resulted from the weathering of the metal sulfides to sulfates. This reaction occurred because the ore deposits were abundant and because the oxygen content of the Earth's atmosphere was by then high enough to weather the sulfides.

(Primitive non-nucleated organisms called cyanobacteria, or blue-green algae, filled the world with oxygen through photosynthesis in the first billion years of life. They absorbed water, kept the hydrogen for energy, and released oxygen, increasing the concentration of this gas in the atmosphere. Oxygen is thought to have first become a significant atmospheric component [about 2.4 billion years ago](#).)

With the weathering of the ore deposits came the delivery of the precious heavy metals, namely zinc, copper, and molybdenum, to the shallow-water environments where life was thriving. "These metals were used by early cells to develop enzymes that enabled them to carry out a greater diversity of functions and begin to sexually reproduce," said Parnell to *New Scientist*. "They gave early life the added dimension of natural selection and variability."

Other scientists [have called the team's hypothesis](#) "attractive" and the findings "interesting and intriguing". The prevailing consensus, however, is that primitive organisms got their heavy-metal fix due to changes in ocean chemistry resulting from the increased atmospheric oxygenation.

"I think we should all be cautious about saying, 'Oh, this one factor was the key'," [Anbar said](#) to *Inside Science*. "There are probably multiple factors."

Either the dominant source of metals or not, granite – Earth's "[signature rock](#)" – seems to have played a part in life's development on this planet.

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# 'Eyes' of Herschel survey enigmatic region beyond Neptune

## How trans-Neptunian objects can help us understand our Solar System and its formation

Since its discovery in 1930, Pluto had a special place as one of the planets of the Solar System... until 2006. In August that year, Pluto and other similar objects were the subject of controversy because the term 'planet' was redefined: from then on, only celestial bodies that dynamically dominate their orbital region (among other criteria) would be considered planets. Pluto, in part because of the many small bodies – more than 1,500 were discovered so far – that inhabit the region beyond the orbit of Neptune, lost its planet status. It is now a dwarf planet, part of a group of remote and very cold objects beyond Neptune called trans-Neptunian objects (TNOs).

But these objects also have a special place in the Solar System. They represent the primitive remnants of the disk from which the planets formed, and they inhabit the region where terrestrial water might have originated from. Researchers from the Max Planck Institute for Solar System Research in Germany [have recently confirmed](#) that the water of a comet originating in the TNO region has the same composition as the water in our oceans. Scientists are trying to learn about the formation and evolution of the Earth and the Solar System, and TNOs offer several clues.

The physical properties of these TNOs are largely unexplored and the thermal properties are difficult to measure, mainly because these objects are far away. But recent studies, combining new observations carried out with the Herschel Space Observatory and sophisticated models to interpret the data, reported physical and thermal properties of a sample of TNOs. These findings are of significance because they provide unique and important constraints on the almost unprocessed material coming from the frontiers of the Solar System, and on the formation and evolution of the Solar System itself. TNOs represent a fingerprint of the planet-formation era.

### Difficulties in determining TNOs thermal properties

The dynamical characteristics of TNOs, such as velocity and orbit, are relatively easy to determine with visible-light telescopes on Earth – and have allowed astronomers to divide TNOs into clubs or dynamic groups. These observations revealed a variety of inclinations of TNOs' orbital planes resulting in a complex orbital architecture, which astronomers cannot yet fully explain. To find out why different groups of TNOs have distinct dynamical properties, scientists need to measure other characteristics of these objects.

Further, measuring physical properties such as size and albedo (percentage of reflected light: low albedo is indicative of a dark surface material like tholin, and high albedo of pure ices) is particularly significant in identifying candidate dwarf planets like Pluto. These Sun-orbiting objects are large enough for their self-gravity to crush them into a nearly round shape but, unlike planets, dwarf planets do not dynamically dominate their orbital region. Objects with more ice (high albedo) become round at smaller sizes than those with more rock – a high-albedo TNO with a diameter larger than about 400 km is considered a strong dwarf planet candidate.

However, estimating physical properties of TNOs is considerably harder than measuring their velocities and orbits, since it requires observations in wavelengths other than the visible. Measurements of thermal emissions, which peak at far-infrared wavelengths, offer the best available means to determine those physical properties. But these wavelengths are mostly absorbed by water vapour in the Earth's atmosphere; therefore, they can be best detected from space.

### Herschel comes to help

The Herschel Space Observatory, one of the cornerstone missions of the European Space Agency (ESA) with participation from NASA, is delivering a wealth of observations of celestial targets in the far-infrared and sub-millimetre wavelength range, including objects in the region beyond Neptune. Herschel, with its 3.5-m-diameter telescope (the largest infrared telescope in space) and three scientific instruments onboard, is the only space facility ever developed to fully cover these parts of the electromagnetic spectrum.

In the framework of the Herschel Open Time Key Programme [TNOs are cool: A survey of the trans-Neptunian region](#), led by Thomas Müller of the Max Planck Institute for Extraterrestrial Physics in Germany, measurements of around 130 TNOs are being obtained. The team recently reported fundamental properties of TNOs in various studies published in the journal *Astronomy & Astrophysics*. Astronomers believe different TNO groups are the outcome of the various evolutionary processes that sculpted the Solar System. Therefore, it is crucial to investigate the physical properties of TNOs in the different clubs to grasp these various processes.

### Pluto-like bodies

Some TNOs show dynamic behaviour similar to that of the dwarf planet Pluto (i.e., with an orbital velocity 2/3 of Neptune), being called Plutinos. Recently, Mommert and collaborators published sizes and albedos of 18 Plutinos – the largest sample to date – based on dedicated Herschel observations. The sample comprises objects which, with the exception of Pluto, range from 150 to 730 km in diameter and between 0.04 and 0.28 in albedo. Some models predict Pluto-sized objects (~2,000 km in diameter) in this club, but future surveys are needed to discover if such objects do exist or if models need to be revised.

### Scattered and detached objects

Other TNOs have highly elliptical orbits and sometimes high orbit inclinations: they are members of the 'scattered disk objects' or SDOs club, and their formation is still poorly understood. Another group of TNOs are well outside Neptune's orbit – beyond 50 times the Earth-Sun distance – and are named detached objects.

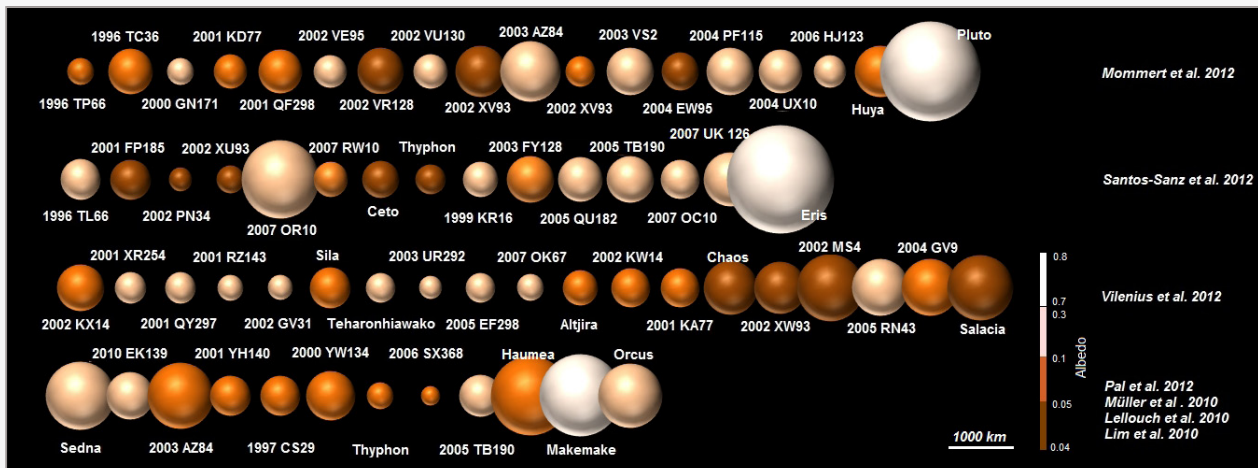


Diagram showing relative sizes of the population of TNOs already published, based on Herschel data (Credit: Miriam Rengel)

From Herschel observations, Santos-Sanz and colleagues have recently characterized 15 SDOs and detached objects, measuring their size, albedo, and other properties. Aside from Eris – a large dwarf planet, – diameters of the sample ranged from 100 to 1,280 km, and low albedos (from 0.04 to 0.09).

Interesting objects in this group include 2010 EK<sub>139</sub>, and Sedna. As reported by Pál and collaborators, 2010 EK<sub>139</sub> turned out to have more than a quarter of Pluto's diameter and an albedo higher than previously believed, indicating that the surface might be covered by a large fraction of ice making the object a plausible candidate for a dwarf planet. Sedna is peculiar because of its orbit: it is the most distant detached TNO known, and is therefore important in determining the edge of the Solar System population with perturbed orbits.

### Left out: The classicals

Another study, focusing on TNOs that do not belong to any other club and have nearly circular orbits, found yet other large objects. Vilenius and colleagues measured the diameters and albedos of 19 of these so-called classicals and found large objects, such as 2002 MS<sub>4</sub> and 120347 Salacia, among them. They also found the sample to be diverse in terms of albedo. Curiously, these members represent the superposition of two different subclasses, the cold and hot populations, which have high or low inclinations, respectively. Their study found that these TNOs with high inclinations have higher albedos than the TNOs with low inclinations. Most scenarios suggest that the cold and hot populations may have originally formed in different regions, and migrated during early Solar System evolution.

### When size matters: Is Pluto the largest TNO?

Previous direct imaging suggested that Pluto's 'twin' Eris was about 5% larger than Pluto, which itself has a diameter of about 2,000 km. More recently, Eris occulted a faint star and astronomers measured a smaller Eris size than previous measurements, but still in the size-range of Pluto. Since the atmosphere of Pluto prevents accurate measurements of the location of its surface, researchers have not yet been able to confirm whether Eris is larger than Pluto. In the old nomenclature, Eris would clearly be a planet.

Herschel is helping to determine if Pluto is indeed the largest object beyond the orbit of Neptune and find more about Eris and other large TNOs. Further, the growing samples of the various clubs observed with Herschel, and the detailed characterization of these objects, will provide information on the present and the original size distribution of these bodies, remnants of the formation of the Solar System. Herschel results will now be fed into formation and evolution models, which will help scientists draw a more accurate picture of our Solar System, our immense home.

Many large TNOs are worlds of their own. With moons, icy surfaces, and (very likely thin) atmospheres, they would likely have been called planets in former times. They can tell us many things about the early stages of the Solar System, and maybe even about how Earth formed and gained its water and organic materials.

One thing is clear: there is still much to find out about the intriguing, distant, icy bodies beyond Neptune.

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