

# CAN STORM WAVES MOVE A BOULDER AS HEAVY AS SIX BLUE WHALES?

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DR RÓNADH COX



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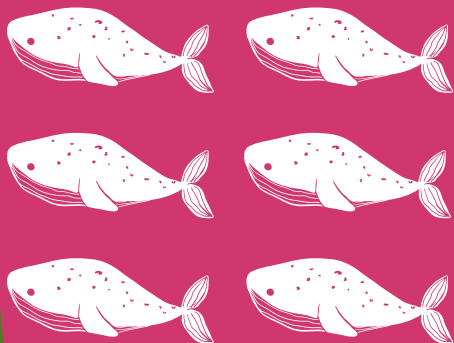
SCIENTISTS USED TO THINK THAT ONLY TSUNAMIS WERE CAPABLE OF MOVING GIGANTIC ROCKS FAR INLAND AND ABOVE HIGH WATER. GEOLOGIST DR RÓNADH COX NOW HAS THE EVIDENCE TO PROVE THAT STORM WAVES CAN BE JUST AS POWERFUL



## IMAGINE THIS

Imagine a rock weighing 620 tonnes. That rock will be four times heavier than a house, or about the same as six blue whales. Now visualise ocean waves rolling toward the shore. Imagine the waves crashing against that rock so strongly that they're able to move it. Storm waves can unleash tremendous energy on coastlines, but the extent of the damage they can do is only beginning to be understood.

More than 600 million people (around 10 per cent of the world's population) live in coastal areas less than 10 meters above sea level. That's a lot of people vulnerable to storms. So, it's the job of scientists to make sure that we understand how big and energetic storm waves can get.



West of Ireland, three rocky isles known as the Aran Islands guard the mouth of Galway Bay. Each island is home to a few hundred people, who live on the sheltered eastern sides, and to thousands of gigantic boulders on the exposed west coasts. For a long time, some scientists thought that these boulders were too huge to be moved by storms, and assumed that they had been left behind by an ancient tsunami. But recently, geologists showed that this assumption was wrong. In 2013-14, a set of very strong storms battered the islands, shifting boulders way above the shoreline: some were on 26-metre-high cliffs, and others were almost a quarter of a kilometre inland. Some of the boulders weighed 10s or 100s of tonnes. The largest was 620 tonnes.

## HOW DID RÓNADH'S TEAM PROVE THE ROCKS HAD MOVED?

The key evidence came from before-and-after photographs that were linked to map locations. Back in 2008, Rónadh visited the area with a student, Danielle Zentner, to study the boulders. They were looking for hard evidence of whether tsunami or storm waves had moved these huge rocks, and so they began to measure, photograph and map the locations of boulder deposits on the Aran Islands. More students took an interest in the project, and over the years they gathered key information, including the weight and precise locations of thousands of boulders, and photographed them.

After the big storms hit the west coast of Ireland in 2013-14, Rónadh returned to the Aran Islands with a team of seven students. This time, they were armed with photographs and measurements. The research team visited all of

the sites and compared the photographs they had from previous years (on iPads) with the locations of boulders. It was apparent that many boulders hadn't moved. But many others had: some had travelled 10s of metres, some had been hoisted up and over other boulders, and some had disappeared entirely! In places, solid bedrock had been ripped up to make new boulders.

"We were able to make graphs – simple XY plots – showing relationships between boulder weight and distance inland, height above sea level, and coast steepness – and also between those topographic variables and the distance the boulders moved. These are very basic measurements and diagrams (not rocket science!), but nobody had shown these relationships before," explains Rónadh.

## WHY DID PEOPLE THINK A TSUNAMI HAD MOVED THESE BOULDERS?

"Storm waves have shorter periods than tsunami," says Rónadh. The period is the amount of time a wave takes to pass a point. Big storm waves can take 10-15 seconds, but a tsunami is much longer, lasting many minutes. Tsunamis are destructive because the flow of water continues for a long time, engulfing and pushing objects as it goes. But because storm waves at the coast form surf that flows in and out in just a few seconds, people thought they lacked the sustained force to dislocate giant blocks. Thanks to Rónadh and her students, we now understand more about the power storm waves and surf can exert.

## WHY IS IT IMPORTANT TO STUDY BOULDER MOVEMENT?

Scientists have been studying transport of sand



Measuring rocks with attitude!



**DR RÓNADH COX**

Edward Brust Professor of Geology and Minerology Williams College, USA



**FIELD OF RESEARCH**

Geology



**CV**

BSc in Geology, University College Dublin, Ireland; PhD in Geology, Stanford University, USA



**RESEARCH PROJECT**

Rónadh and her team of students have measured, photographed and documented the location of over 1,100 giant boulders that were moved by storms on the west coast of Ireland. Her work has helped prove that storm waves can move rocks weighing hundreds of tonnes.



**FUNDERS**

National Science Foundation and Williams College Class of 1963 Sustainability Fund

and small rocks on coastlines for a long time, so we know lots about the impact of storms on beaches in coastal areas where people live. These places tend to experience lower-energy waves compared to areas such as the Aran Islands. But as sea level rises, and climates change, it's possible that storminess may increase. We therefore need to understand the highest wave energies, to understand how much coastal damage storm systems can cause.

Before Rónadh's research was published, people didn't realise that storm waves could move

boulders as heavy as six blue whales – or heavier. The largest boulder on the Aran Islands weighs more than 700 tonnes. It didn't move during the 2013-14 storms, but evidence shows that it moved in the past. If scientists are to accurately understand and predict risks associated with living in coastal areas, understanding boulder transport is vital. And the world needs more geologists to work on these problems!



This giant boulder weighs 620 tonnes! It moved during the winter storms of 2013-14, and it's the largest rock known to have been moved by storm waves.

**RÓNADH'S TOP TIPS FOR STUDENTS**

Go to college and take an introductory geology or geoscience class (they're the same thing). That will put your feet on the path, and that path can take you anywhere – literally. The whole world is made of rocks!

Talk to a geologist. If you don't know any, find one or two on Google and send them an email. Most of us are happy to talk to people who are interested in the planet and want to know what a geoscientist does.

# ABOUT GEOLOGY

Rónadh has been studying and working in geology for nearly 40 years. We ask her why becoming a geologist is a good career choice.

## WHY DO WE NEED GEOLOGISTS?

Lots of reasons! But here are a couple. First, most of our natural resources come from the Earth. As the saying goes: 'If it can't be grown, it must be mined'. From the metal in your fizzy drink can, to the necklace around your neck, to the 70+ components in a computer screen, a geologist had to figure out where to find the ores to create all these things.

Second, we live in a dynamic world, subject to floods, landslides, earthquakes and

eruptions. Geologists are the people who try to understand these processes, and help communities decide how to manage natural hazards and where to build.

## WOULD YOU SAY GEOLOGY, OR THE GEOSCIENCES, OFFER GOOD JOB PROSPECTS?

Very much so. You can get a geology job with just a bachelor's degree. And if you decide to pursue an advanced degree, you can get paid to do that. Students are awarded fellowships to cover tuition costs and are paid a salary. Graduates go into teaching, environmental engineering, resource exploration, conservation, management,

climate science – all kinds of things. Some even use their geology background to kick start careers in law or politics.

## WHAT EXCITES YOU ABOUT YOUR RESEARCH AND GEOLOGY, MORE GENERALLY?

Geoscience teaches us to look at the planet and ask questions. I love to walk around wondering how things formed. People who know geologists joke that you should never drive with them, because they spend all their time looking out of the window at rocks instead of watching the road. Geology makes the world come alive!

*“ Geologists get jobs with just a bachelor's degree, but if you decide that you want to move on to an advanced degree, you can get paid to do that. ”*



*Rónadh's team of undergraduate field researchers stands next to a truly titanic boulder.*



*Along the Aran Islands' Atlantic coast, there are 15 km of boulder deposits.*



*Piles of boulders sit on top of 40 m cliffs, 25 m inland from the edge. To understand the scale of this, look at the people near the cliff edge.*

# ASK DR RÓNADH COX

## WHAT DID YOU WANT TO BE WHEN YOU WERE YOUNGER?

I always wanted to work in the natural world. I was fascinated by stories of adventure and exploration, and also by animals. Initially, I wanted to be a marine scientist or a biologist.

## SO, HOW DID YOU END UP FOLLOWING IN CAREER IN GEOLOGY?

I went to college planning to get a degree in biology and hoping to have a career that would involve adventure and exploration outdoors. I took geology as my fourth course because I didn't want to do physics (I've always been shy of maths, although over the years I've discovered that maths is pretty badass!) It didn't take long, just a few weeks, before I was sucked in by the concepts of plates, earthquakes, deep time and the way the earth works.

## YOU GREW UP IN IRELAND. WHY DID YOU CHOOSE TO STUDY AND WORK IN THE US?

I went to University College Dublin and had never lived anywhere else. When I decided to do a PhD, I thought it would be fun to live

and work in a foreign country, so I applied to universities in the US. I had planned to come home to Ireland after I got my degree, but I met my husband in graduate school. He's also a geologist, and we both wanted to work in research and teaching. The US is where we both managed to find college jobs.

## YOU'RE CURRENTLY BASED AT WILLIAMS COLLEGE, IN MASSACHUSETTS, USA. WHY ARE YOU STUDYING BOULDERS ON THE WEST COAST OF IRELAND?

My motto is: 'The whole world is made of rock. Why not study it someplace interesting?' Geoscience is a ticket to anywhere and everywhere. I'm studying the west coast of Ireland because it turns out that its boulders are some of the most impressive in the world.

## WHAT DO YOU LOVE MOST ABOUT YOUR JOB? AND WHAT ARE YOU NOT SO KEEN ON?

I love field research. I love teaching students. I especially love teaching students in the field. I love solving puzzles about how the Earth works. I love that I get to walk along some of the most beautiful coastlines in

the world, and that I get paid to do it! #theWorldIsMyOffice. I don't like grading and I don't like administrative work, but you gotta do what you gotta do.

## IF YOU COULD GO BACK IN TIME WHAT ADVICE WOULD YOU GIVE YOURSELF WHEN YOU WERE STARTING OUT ON YOUR CAREER PATH?

Take chances! Don't be afraid to make mistakes or to fail. But own your mistakes and your failures; learn from them and move on. Your failures don't define you, but they can make you stronger and help you create your successes. It took me six years to get my four-year degree because I failed courses and made bad choices and prioritised social life over work. But I learned, I grew up, and here I am. It's all good!

## OPPORTUNITIES IN GEOSCIENCES

- According to GlassDoor, geologists with just a bachelor's degree earn \$63,000 on average
- Some industries pay more. For example, government geologists earn on average \$103,000 or more (FederalPay.org), and geologists in the oil industry earn on average \$150,000 per year.
- Lots of employers seek people with a degree in geoscience. The energy sector (oil, gas, wind, waves) and environmental firms hire geologists, but there are also opportunities elsewhere. The National Park Service, for example, offers paid internships for college students and recent graduates.
- It's important to remember that students enrolled in geoscience PhD programmes are usually paid while studying for their degree (see PhD Stipends).



Meet JoJo. She's on a field expedition studying boulder erosion. You can be a field geologist, too, and measure the natural world.

# GEOLOGY WITH DR RÓNADH COX

## TALKING POINTS

- 1) Why is it important for geologists like Rónadh to help us and society understand the power of storm waves? (See *Imagine this*, p1)
- 2) How heavy was the heaviest boulder that was moved by the storm waves of 2013-14? (See first paragraph of the article, p1)
- 3) What evidence did Rónadh and her team have to prove that boulders weighing 10s or 100s of tonnes had been shifted by storm waves and not a tsunami? (See *How did Rónadh's team prove the rocks had moved?* p1)
- 4) Rónadh and her research team made graphs using topographic variables to show just how powerful storm waves can be. What topographic variables did her team base the graphs on? (See *How did Rónadh's team prove the rocks had moved?* p1)
- 5) The main difference between a storm wave and a tsunami wave is the period. Can you explain what this is? (See *Why did people think a tsunami had moved these boulders?* p1)
- 6) Why did some scientists assume that an ancient tsunami had moved the boulders and not storm waves? (See *Why did people think a tsunami had moved these boulders?* p1)
- 7) Rónadh says there are lots of reasons to become a geologist. What are the two reasons she lists? Can you think of any others? (See *Why do we need geologists?* p3)

## USE A MOBILE PHONE APP TO MEASURE YOUR FRIEND!

Photogrammetry lets us measure objects by taking photos of them. CGI (computer-generated imagery) in films and video games uses photogrammetry to make scenes look more realistic, but it's also used by scientists such as geologists to measure things in the natural world. You can give photogrammetry a go using your phone. There are lots of free apps available, and once you have downloaded one you can make a 3D image of a chair, a cup, or even a friend! Just make sure you check with your teacher or parent before downloading a photogrammetry app.

## HOW DO YOU FIGURE OUT THE WEIGHT OF SOMETHING YOU CAN'T WEIGH?

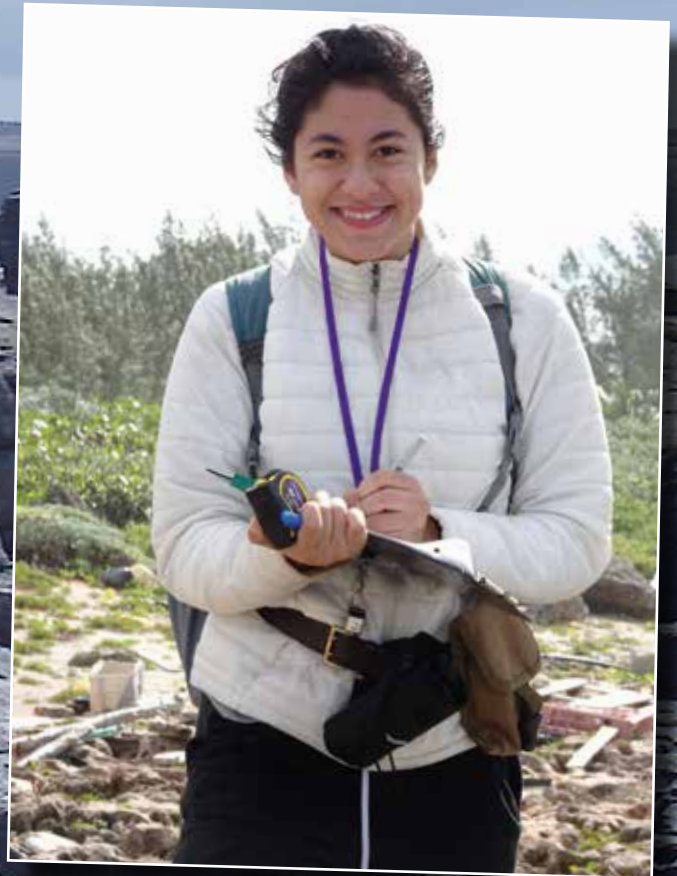
You can't put a gigantic boulder on a weighing scale, so how did Rónadh and her team know how heavy the rocks were? Easy! You can calculate the mass of anything, without weighing it, if you know its volume and density because  $\text{mass} = \text{volume} \times \text{density}$ . It's that simple.

Volume is the amount of space a thing takes up. Measures of volume include litres, gallons, teaspoons, cubic metres ( $\text{m}^3$ ) or cubic centimetres ( $\text{cm}^3$ ). Measure an object's height, width and depth, and multiply these measurements to get volume:  $\text{height} \times \text{width} \times \text{depth}$ . If the object measures  $1 \text{ cm} \times 2 \text{ cm} \times 3 \text{ cm}$ , what is its volume?

Density tells you how much matter is packed into an object. For example, a shotput and an orange may be the same size, but the shotput is heavier and therefore denser.  $\text{Mass} = \text{volume} \times \text{density}$ , and  $\text{density} = \text{mass}/\text{volume}$ . If an object weighs 15 g and its volume is  $6 \text{ cm}^3$ , what is its density?

It's easy to measure the density of small objects. Measure mass (or weight) in kilograms and divide that by volume ( $\text{height} \times \text{width} \times \text{depth}$ ), and you have the density. But what about huge objects like boulders? Luckily, the densities of rock and other substances are known, so you can look them up. For example, the density of iron is 7.87 grams per cubic centimetre ( $\text{g}/\text{cm}^3$ ), and many rocks are about  $2.5 \text{ g}/\text{cm}^3$ . So, if you calculate the volume (remember:  $\text{height} \times \text{width} \times \text{depth}$ ), you simply multiply this by the density to get the weight. Easy.

Now you're thinking like a geologist! Try measuring the mass, density and volume of objects around the room. Be creative!



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