DR RÓNADH COX

A **helping** hand

Studying the erosion of Madagascar's unique landscape has allowed geologist **Dr Rónadh Cox** to offer Malagasy students unique opportunities to realise their full professional potential, as she explains here

What is the origin of this research project?

In the early 1990s I was working on hard-rock projects in Madagascar, but as I travelled around I was intrigued by the spectacular gullies on the hillsides. They are called 'lavaka', which is the Malagasy word for 'hole'. The standard narrative is that they are caused by human activity, but that didn't make sense to me because many areas that are heavily gullied are almost uninhabited, whereas other places where people have been living for centuries have few or no lavakas. I realised there had to be more to the story, but there was very little previous work on these features. So Michel Rakotondrazafy and I decided it would be worthwhile to investigate lavaka formation and erosion from a variety of angles. The questions are geologically interesting and also relevant to the Malagasy people, which makes it a rewarding study.

You are also working on questions of tsunami versus storm wave movement of boulders. Could you explain more about this?

Far from Madagascar, the Aran Islands off the coast of Ireland have huge boulder deposits along cliff tops. They have been interpreted both as storm wave and tsunami deposits, and figuring out which is correct is important for understanding coastal dynamics – not just for Ireland, but for high-energy coasts worldwide. There have been no tsunami in the northern Atlantic for hundreds of years, but my co-authors and I were able to show that the boulder ridges have migrated since the middle of the 19th century. Our key observation comes from geographic information systems (GIS) comparison of 19th century ordnance survey maps and modern orthophotos of the Aran Islands, which show clearly that in some places the boulder ridges have migrated inland and overrun old field boundaries. This result can be exported to other places because there are a

number of locations around the world – subject to both storms and tsunami – where similar deposits occur, and people argue over the causes. We have shown that you can't just look at big boulder deposits and assume they were moved by tsunami. Our research, published in the *Journal of Geology*, demonstrates that storm waves are indeed capable of doing this work. It is a different kind of erosion question than the Madagascar project, but has similarly broad relevance to social questions: using geoscience to help understand processes that affect human populations.

How does the Madagascar-Massachusetts collaboration heighten the impact of your research?

Michel Rakotondrazafy and I make a good team. We each play to our strengths within our home systems. I write our grant proposals and have access to labs through other collaborators in the US; and Michel knows the terrain and geography of Madagascar, and negotiates the tricky waters of the complicated bureaucracy to make our sampling campaigns successful. In the field we collaborate in all aspects of the data and sample collection, and we combine forces in teaching the American and Malagasy students who work with us. Rakotondrazafy periodically visits the US to meet US geologists and present research results at the Geological Society of America annual meeting, and we jointly select Malagasy students who come to study at Williams College. We have been co-authors on a number of papers over the years. The work is richer and deeper because of our joint involvement.

How do you integrate Malagasy students into the international science community?

It is critically important to provide professional opportunities for Malagasy students: their economic realities and high costs of air transport to and from Madagascar put international study out of the reach of most. Since 2002 we have been able to bring four students to study and do research for one or two semesters at Williams, funded by the National Science Foundation because of the scientific and broader impacts, and also made possible by the cooperation and support of Williams College. The Malagasy students gain new educational experiences and are exposed to different scientific approaches. They live and work with American and other international students, which plugs them into a wider intellectual community. The students do not get a degree from Williams, but they can use this base, and letters of recommendation from professors here, to apply for graduate programmes in the US This may be one of the biggest impacts of our work. We are helping these Malagasy students achieve in ways that would be difficult or impossible for them otherwise, and the four we have worked with to date are all on track for successful careers.

Fact not fiction

In Madagascar, a country synonymous with environmental degradation, researchers from **Williams College** and the **Université d'Antananarivo** have called conventional interpretations of erosion into question

OPEN ANY BOOK or article on Madagascar, and you will read that it is one of the world's most erosion-ravaged countries, suffering severe human-caused land degradation – but these claims come from subjective interpretations of the landscape, not field measurements. Together, Dr Rónadh Cox from Williams College in Massachusetts, and Dr Michel Rakotondrazafy at the Université d'Antananarivo in Madagascar are changing how we think about erosion in Madagascar by researching gully (lavaka) formation, and by measuring long-term regional erosion rates (using cosmogenic isotopes). They hope to paint a truer picture of how the Malagasy landscape evolves by understanding the roles of both natural and anthropogenic processes. Cox explains that the phenomenally high erosion rates for Madagascar that are frequently repeated come from studies decades old and were collected in just a few small areas. There are in fact few actual datasets, and no regional measurements: "We want to collect lots of data and gain solid information about erosion rates, how they vary from place to place, and hopefully how they have changed since the arrival of humans in this country – which is only about 2,000 years ago," Cox outlines. Ultimately, their work may result in pragmatic approaches for more effective and sustainable management of Madagascar's terrain.

THE MYSTERY OF THE LAVAKA

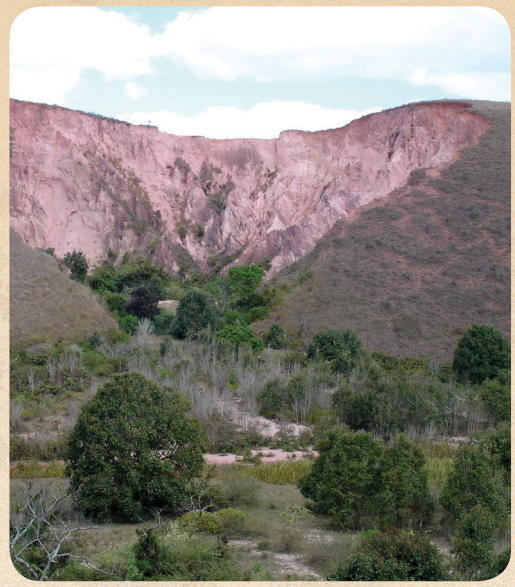
Cox and Rakotondrazafy launched this project in the early 2000s. Cox was intrigued by the lavakas that were visible on many of the hillsides. The standard explanation was that the lavakas resulted from human land use, but Cox realised that it was difficult to separate fact from fiction in these reports: "There was no shortage of people willing to tell the world that lavakas, and erosion in general, were entirely due to the Malagasy people, lack of evidence notwithstanding," she states. Cox persuaded her colleague Rakotondrazafy that this was an interesting problem, and the idea was born for a research programme combining lavaka mapping with isotope analysis of stream sediment (using cosmogenic ^{10}Be) to develop a baseline for background erosion rates.

While Malagasy people are concerned about the adverse effects of lavaka erosion on agriculture and infrastructure, there is little knowledge of how these holes form. Options to reduce and minimise this erosion are limited because there is insufficient information to ensure that the best approach is being taken. Locals generally attempt to stabilise the hillsides by planting non-native Vetiver grass in the lavakas or planting the slopes with non-native Eucalyptus and conifer tree species, but with limited success. Rakotondrazafy points out that the non-native tree planting techniques currently in use are notably unsuccessful in stopping lavaka erosion, and can have a negative effect on the local water table: "Sometimes, when people plant Eucalyptus, all the springs around the hill disappear, and sometimes small lakes vanish". When the causative factors are poorly understood, it is nigh impossible to develop effective preventative strategies. So Cox and Rakotondrazafy are convinced of the need to solve the mystery of what causes lavakas to form and what drives Malagasy erosion.

A COMBINATION OF FACTORS DRIVING EROSION

Mapping lavakas on the ground and by geographic information systems analysis of satellite images has helped illuminate their associations. Work soon to be published in the *South African Journal of Geology*, first-authored by Cox's and Rakotondrazafy's student Ny Riavo Voarintsoa, shows that bedrock geology plays little role in lavaka formation but that hillslope angles are critical. They have also found that the highest erosion rates occur in specific bioclimate zones and that a combination of temperature and aridity index appears to have an effect. The group recently published a paper in the scientific journal *Geology*, showing that lavakas are generally found in earthquake prone areas. Cox points out that, rather than being a unique consequence of human activities, lavakas are a natural erosional response in this landscape: "The gullies are not formed by earthquake events, but somehow – in ways we do not yet understand – frequent low-grade seismic shaking pre-conditions the deep soils in these hillslopes cause them to collapse and form lavakas during the rainy season".

The other great unknown is how erosion rates in Madagascar have been affected by human activities. The team has begun to address this question via a nation-wide stream-sampling campaign. By measuring the amount of cosmogenic ^{10}Be in river sand, they can determine the rate at which landscape erosion is occurring. They also sample old river deposits, which they date by ^{14}C analysis of charcoal in the sediment, to see whether the ^{10}Be indicates any difference



in erosion rate between modern and ancient times. The key factor is that humans have been in Madagascar less than 2,000 years, so it is possible to obtain a pre-human erosion signature from the river systems. The research findings on erosion rates are preliminary and the team is still analysing samples, but initial results from one site (published in the *Journal of Geology*, 2010) indicate that erosion rates around a millennium ago were very similar to modern rates.

CHALLENGING TRADITIONAL THINKING

Cox is excited that their findings in Madagascar question current beliefs about the role played by the Malagasy in landscape erosion: "Our initial results suggest that erosion rates have not increased dramatically in the last 1,000 years – although so far that is based on one site only. We are eager to see the numbers from our upcoming analyses to see how that holds up for different areas. This, plus finding a link between lavaka formation and regional seismicity, challenges the 'received wisdom' that erosion in Madagascar is the fault of the locals". She and Rakotondrazafy point out that conventional thinking, which assigns blame for erosion in Madagascar to local land management techniques leads to tension and does not provide effective solutions to the problem. There is clearly a need to move away from obsolete narratives about erosion and make direct measurements across climatic and topographic zones throughout the country.

Cox and Rakotondrazafy hope their research will offer hard facts on erosion rates that are data-based and nuanced with respect to climate, topography and human activity. The team also hope to inform Malagasy farmers and policy makers that erosion has a number of causes:

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"Our desire is to offer people an alternative approach to the problem of soil conservation, and to stimulate the development of a wider range of tools – both educational and applied – for environmental protection of their land," Cox explains. The researchers are keen to make new connections in the community to help create lasting relationships in Madagascar, linking active geoscience research with discussions of policy. They hope to play a collaborative and informative role as farmers, conservation groups and policy makers develop new solutions to the ongoing land management dilemma.

INTELLIGENCE

EROSION IN MADAGASCAR: INVESTIGATING BACKGROUND AND MODERN RATES USING ^{10}BE AND STREAM SEDIMENT GAUGING DATA

OBJECTIVES

To understand rates of erosion, the role of lavakas in sediment generation, and the role of humans in the process to determine whether Madagascar is naturally characterised by high erosion rates or whether they are of recent and anthropogenic origin.

KEY COLLABORATOR

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RÓNADH COX has been a faculty member at Williams College, Massachusetts since 1996. She obtained her BSc in Geology from University College Dublin in 1985 and her PhD from Stanford University in 1993. Cox has been conducting research in Madagascar since 1993.

MICHEL RAKOTONDRAZAFY obtained his Maîtrise de Recherche in 1980, his Doctorat de Troisième Cycle in 1990 and his Doctorat d'Etat in 1995, all from the Université d'Antananarivo, where he has been a Professor since 1995 and Professor Titulaire since 2003.