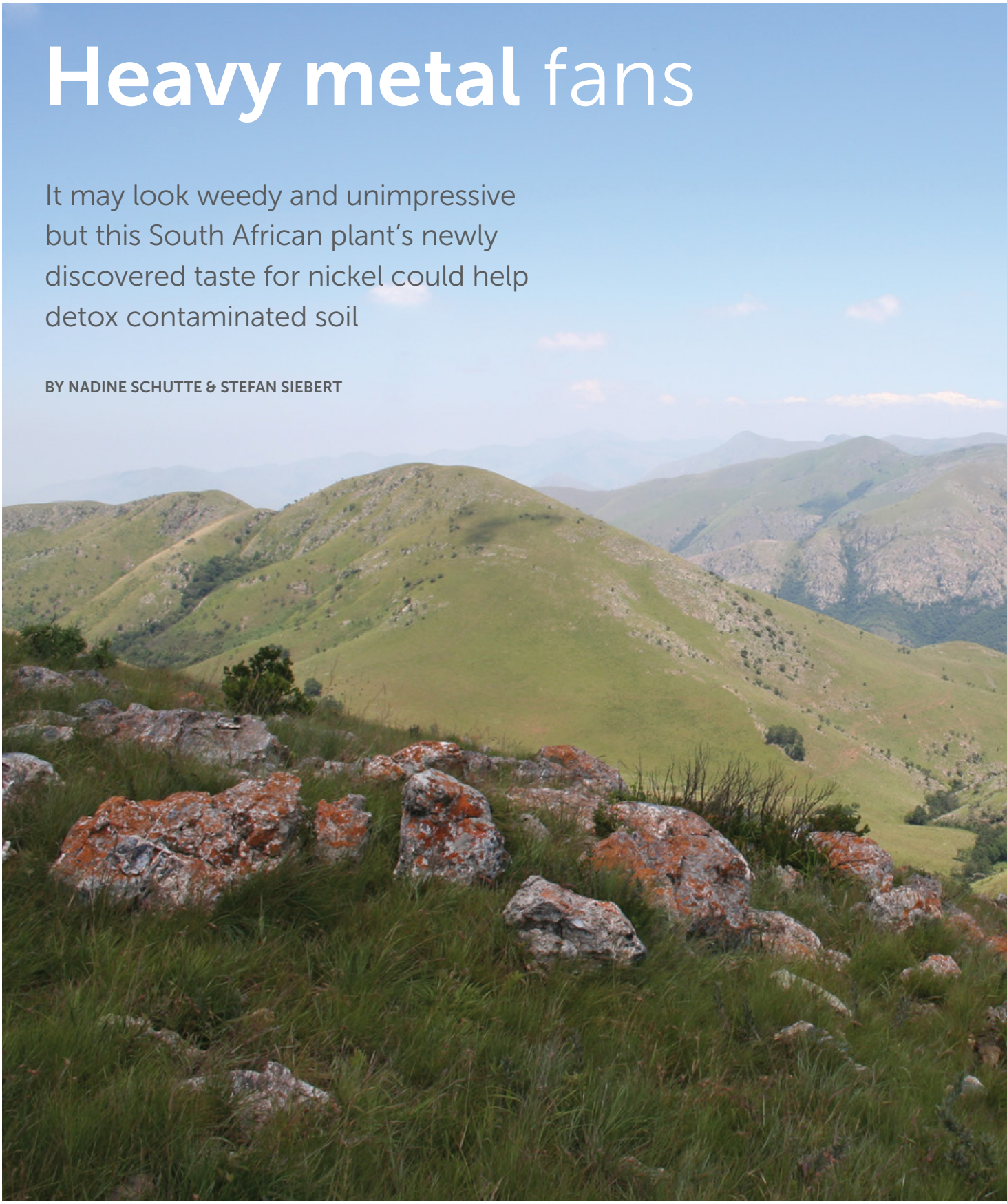
Heavy metal fans

It may look weedy and unimpressive but this South African plant's newly discovered taste for nickel could help detox contaminated soil

BY NADINE SCHUTTE & STEFAN SIEBERT



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The serpentine outcrops of the Barberton greenstone belt are home to several plants that are heavy metal fans including the daisy *Senecio conrathii* (inset).

THE DAISY TOWN is the quaint nickname for Barberton in Mpumalanga. But few visitors realise that some local members of the daisy family have special powers.

Barberton is renowned as a gold-rush town but there are significant quantities of other metals in the area's soils, too. The local serpentine or greenstone soils, for instance, have high levels of heavy metals such as nickel, chromium and cobalt.

Soils with high levels of heavy metals often create an environment where plants can struggle to survive. The Barberton greenstone soils, for example, generally have low levels of nutrients essential for plants such as sulphur and nitrogen. They also have a calcium-to-magnesium ratio of less than one so the higher magnesium content tightens up the soil and hampers water infiltration. But some local plants have adapted very successfully to this.

These 'heavy metal fans' are known as hyperaccumulators because they can accumulate and tolerate unusually high levels of heavy metals. Curiously, though, this does not interfere with their life cycle as they establish themselves, grow and reproduce.

Plants that hyperaccumulate nickel or other metals have evolved numerous times worldwide, in both tropical and temperate regions, including the Great Dyke in Zimbabwe and in Australia. In fact, such plants have adapted so well to this often toxic environment that they can even be used to help decontaminate polluted areas. This is particularly important around mining areas which are prone to high metal waste.

M. KOEKEMOER

STEFAN SIEBERT

International serpentine ecology expert Prof Nishanta Rajakaruna from California inspired the search for more heavy metal fans.

LOOKING FOR SA'S HEAVY METAL FANS

At least five South African daisy family members (Asteraceae) are known to thrive on such high levels of heavy metals. Prof Kevin Balkwill from Wits University previously identified some nickel hyperaccumulators in the Barberton region.

"Could there be more?" we wondered. Inspired by our visiting professor Nishanta Rajakaruna from California Polytechnic State University, an international serpentine ecology expert, we headed off to search the Barberton greenstone belt.

We sampled 20 frequently occurring species of the daisy family (Asteraceae) from eight serpentine outcrops of the Barberton greenstone belt (see map) and found three species that were hyperaccumulating nickel. Two of these – *Berkheya nivea* and the woodland sun daisy (*B. zeyheri*) – were already known to be nickel hyperaccumulators. But we succeeded in identifying a sixth member of the daisy family, the ragwort or groundsel *Senecio conrathii*, as one of these 'heavy metal fans'.

It was a big surprise to us as the area is already very well studied. Two of the new plant's relatives, the woolly grassland senecio *(S. coronatus*) and *S. anomalochrous* have already been identified as hyperaccumulators.

SPOTTING THREE SENECIO HEAVY METAL FANS

M. KOEKEMOER

***Senecio conrathii*.**

B. VAN WYK

***Senecio coronatus*.**

M. KOEKEMOER

***Senecio conrathii*, note serrated leaf margins.**

B. VAN WYK

***Senecio coronatus*, note dense hairs in leaf axis.**

M. KOEKEMOER

The new heavy metal fan that we found, *Senecio conrathii*, might look quite ordinary but it has special powers.

B. VAN WYK

***Senecio coronatus* flowers.**

VAGABOND HEAVY METAL FANS

Hyperaccumulators are often restricted to particular soils, such as the three hyperaccumulating spiny thistles (*Berkheya* species) that thrive on serpentine soils. Instead, like the two other hyperaccumulating ragworts (or groundsels), the new heavy metal fan *S. conrathii* is not restricted to serpentine.

It is widely distributed across eastern southern Africa so its potential to help clean up the environment through hyperaccumulation can also be more widely used. *S. conrathii* is an example of a particularly enterprising vagabond that some might call a weed. It can thrive equally well in soils that are toxic and others by adapting its responses to local conditions (ecophysiologically).

These adaptations can become permanent and then lead to new species developing. This 'evolution in action' also offers a lot of potential to improve the way we use hyperaccumulating plants to clean up polluted soil (phytoremediation).

MAKING HEAVY METAL FANS

Hyperaccumulating plants find heavy metals an advantage rather than a threat. Most plants typically take up beneficial elements from the soil in which they grow as ingredients of their metabolic processes.

Magnesium, for instance, is the centrepiece of the chlorophyll molecule. Zinc is required to produce plant hormones. Phosphorous is required in every enzymatic activity that takes place in the plant.

Plants need only low concentrations of elements to survive. So they do not take up most of the soil's heavy metals.

Hyperaccumulators and some other plants may accumulate much higher levels of an element or elements than they can use. If the plants cannot tolerate this, they may become stressed or even die, often because heavy metal contaminants target their photosynthesis systems.

A few plants, however, are hyperaccumulators that have adapted to tolerate elements that are usually poisonous, especially at high levels.

Hyperaccumulators are able to store heavy metals mostly within their leaf surfaces (epidermis), hairs (trichomes) and cuticle. This process of detoxification and sequestration protects their photosynthetic systems by keeping the heavy metals away from stomata cells.

RECOGNISING HEAVY METAL FANS

Three markers identify the heavy metal fans that hyperaccumulate without problems:

1. They take up heavy metals much faster than other plants.
2. They rapidly move heavy metals up through the roots to the shoots and leaves.
3. They have become able to store large amounts of heavy metals in these organs without being badly affected.

A plant must accumulate a specific critical level of metal to be classified as a hyperacccumulator. Nickel heavy metal fans must accumulate more than 1 000 micrograms of nickel per gram (more than 0.1%) of dry leaf tissue, for example.

This is tested by smearing plant tissue on nickel test paper which will turn from white to red if more than 0.1% of nickel is present in the leaf sap. For more accurate results, plant material can be acid digested and sent to an accredited lab to be analysed by means of mass spectrometry.

Hyperaccumulators can use heavy metals accumulated in their leaves as a way of defending themselves, known as elemental defence. Plant-eating creatures may avoid eating their leaves because they taste unpleasant. This warns herbivores to avoid taking in high amounts of metals that they cannot metabolise and which could ultimately poison them.

Heavy metal fans may not be 100% successful with their elemental defence, however. Some plant-eating insects have evolved the ability to tolerate high metal concentrations in plants. They then accumulate the metals in their own tissue to defend themselves against their own predators.

WHY WE NEED HEAVY METAL FANS

Plants that can hyperaccumulate heavy metals can be harnessed to benefit the environment and even our economy. The fact that we could readily find an unrecognised nickel hyperaccumulator in one field trip of seven days makes us curious about how many more heavy metal fans are out there. We are also disappointed that the hill where we sampled the plant is not environmentally protected. Its greenstone is steadily being mined for curios.

Hyperaccumulator plants are already used to help clean up metal-contaminated soil. As our environment is increasingly polluted by heavy metals through both natural processes and human activities, we need to find more of these easy and effective methods to detoxify polluted areas.

There is already global demand for hyperaccumulators. SA's *Berkheya coddii* is already being used internationally for its ability to tolerate high concentrations of metals, either to stabilise polluted soil or to remove harmful substances.

The heavy metal fans could even give a boost to our economy. Hyperaccumulator plants are already used as a cheap way of extracting valuable metals from polluted soils (phytomining). Instead of disposing of the plants after use as in phytoremediation, phytomining plants are usually harvested then burnt in smelters to release the valuable elements for further processing.

This discovery would not have been possible without the financial support received from the Botanical Education Trust, a project endorsed by the Botanical Society. Prof Nishanta Rajakaruna received a National Geographical Society research and exploration grant.

Nadine Schutte worked on nickel hyperaccumulation for her honours research project. She is now an MSc student at the North-West University, Potchefstroom Campus, currently working on insect diversity of soybean fields; nadineschutte2@gmail.com

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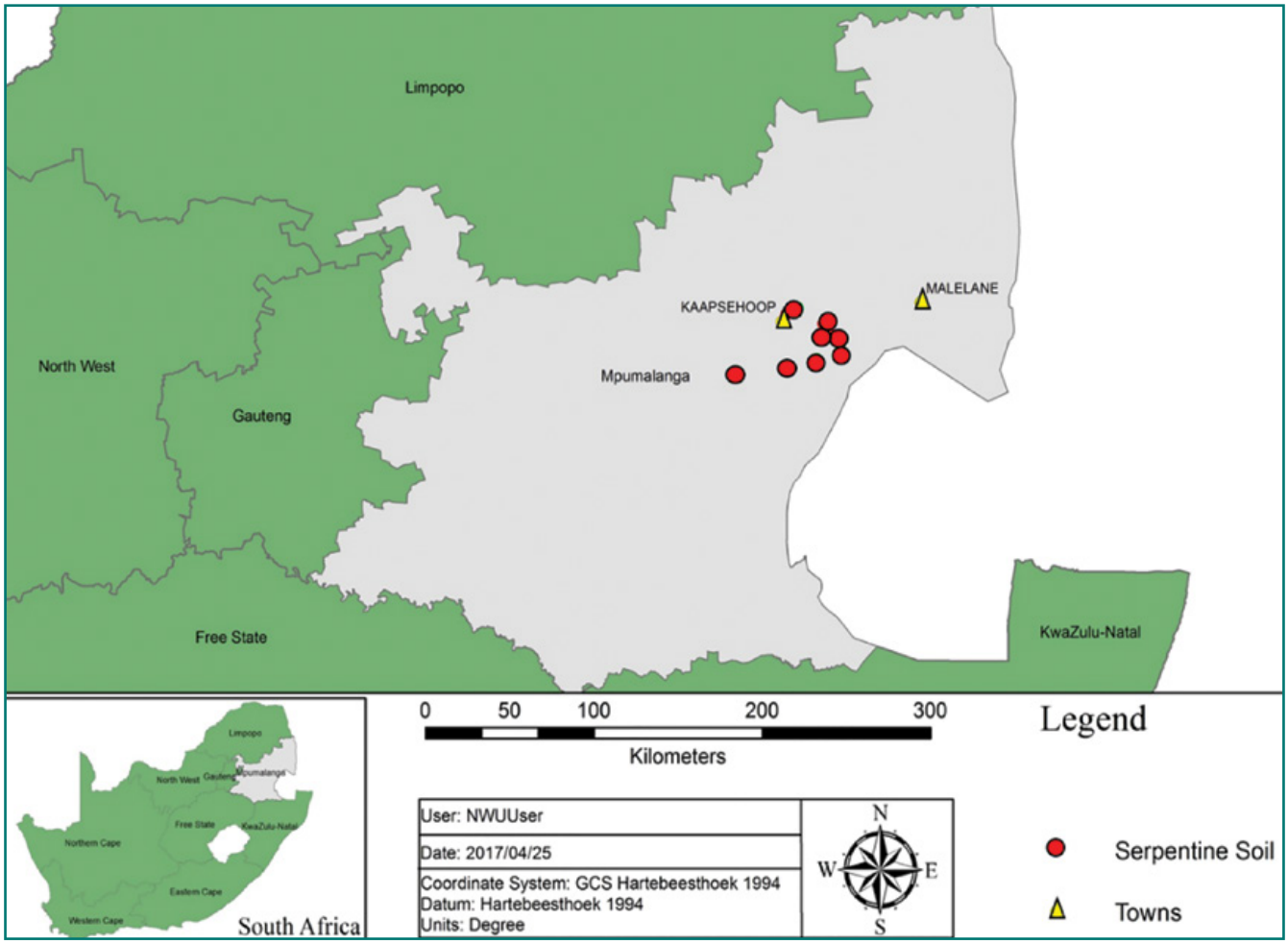

Map showing localities of the eight serpentine study sites along the Barberton greenstone belt, Mpumalanga.

GETTING TO KNOW SENECIO			
	S. anomalochrous	*S. conrathii*	*S. coronatus*
Height	1 m	1.5 m	0.75 m
Flower (capitulum)	Only disc florets (discoid)	Disc and ray florets (radiate)	Disc and ray florets (radiate)
Floret colour	Purplish	Yellow	Yellow
Fruit (achenes) and ovaries	Stiff, hairy (hirsute)	Hairless (glabrous)	Moderately hairy
Leaf shape	Linear lance shaped (lanceolate)	Linear lance shaped (lanceolate)	Broadly elliptic
Leaf edge (margin)	Rounded teeth (crenulate)	Saw toothed (serrate)	Triangular teeth (denticulate)
Leaf axils	Wisps of white cobwebby hairs	Wisps of white cobwebby hairs	Densely hairy