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### Stalagmite memories of ancient rainfall

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## Stalagmite memories of ancient rainfall

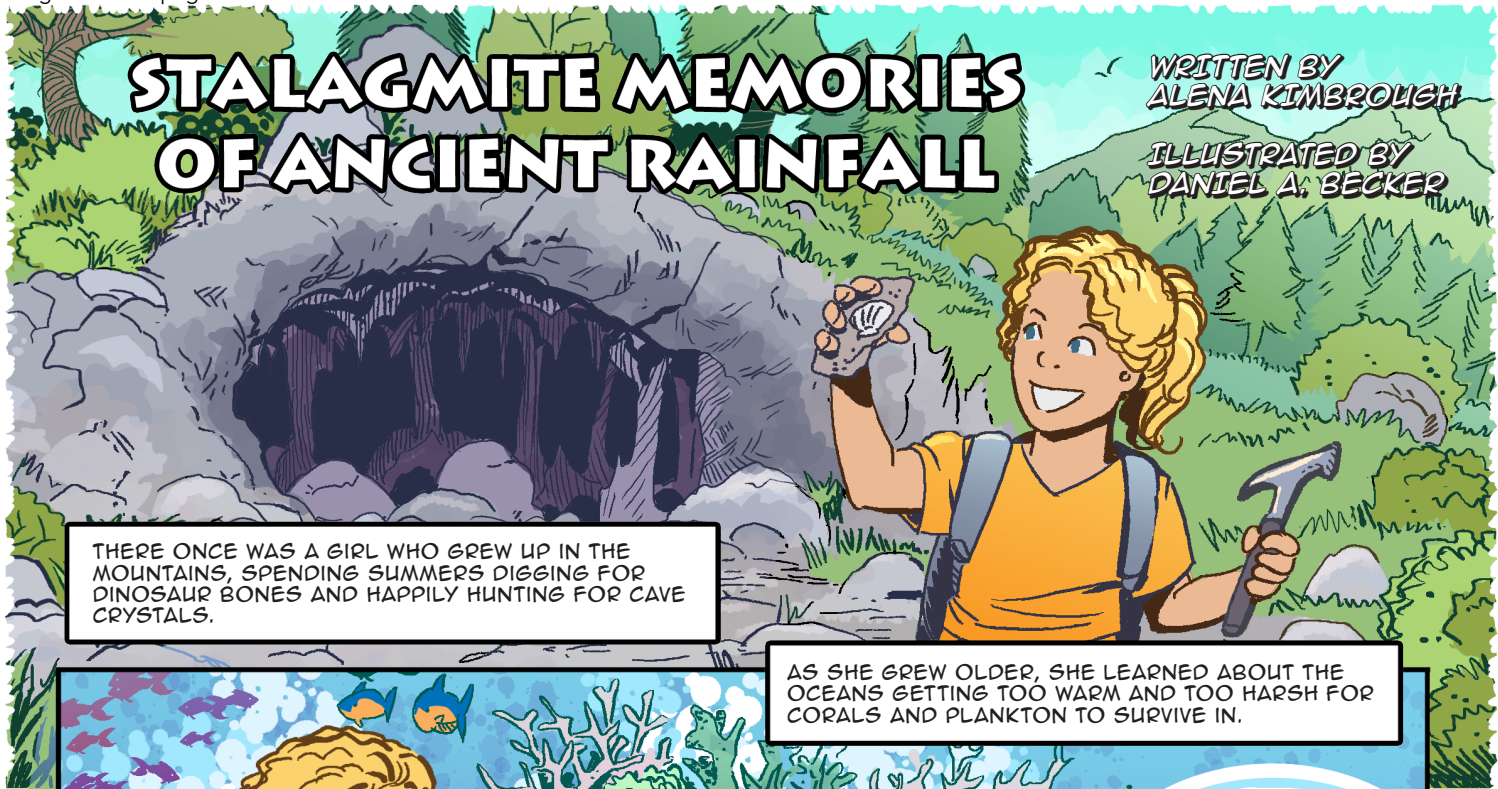
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# STALAGMITE MEMORIES OF ANCIENT RAINFALL

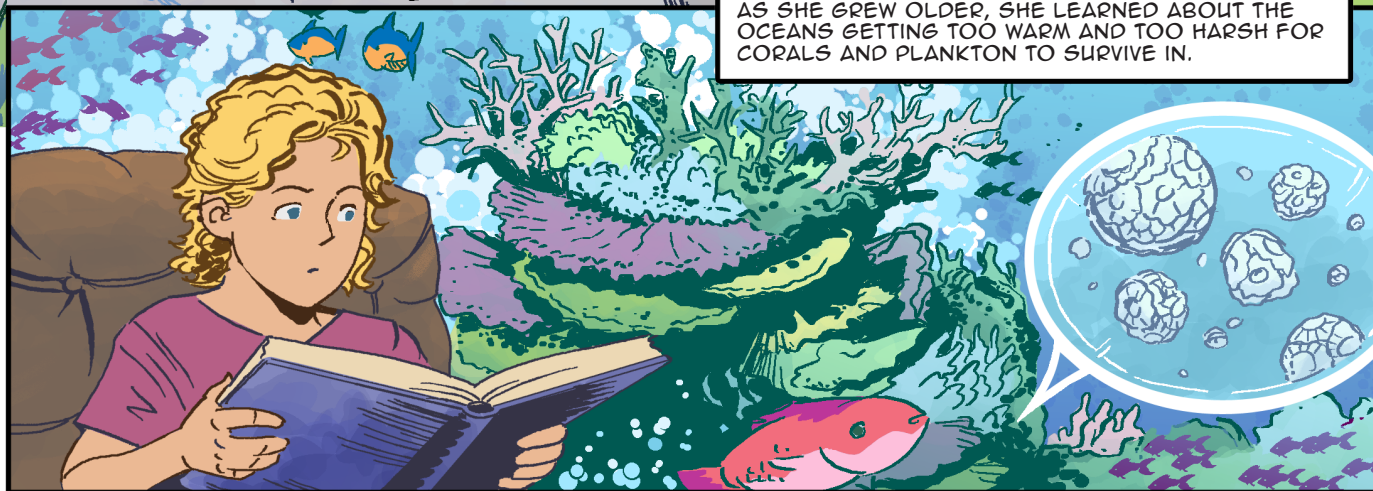
WRITTEN BY  
ALENA KIMBROUGH

ILLUSTRATED BY  
DANIEL A. BECKER



THERE ONCE WAS A GIRL WHO GREW UP IN THE MOUNTAINS, SPENDING SUMMERS DIGGING FOR DINOSAUR BONES AND HAPPILY HUNTING FOR CAVE CRYSTALS.

AS SHE GREW OLDER, SHE LEARNED ABOUT THE OCEANS GETTING TOO WARM AND TOO HARSH FOR CORALS AND PLANKTON TO SURVIVE IN.

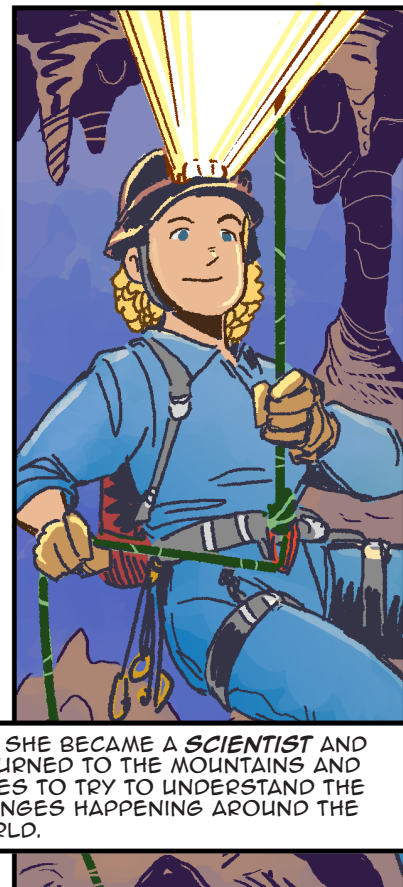
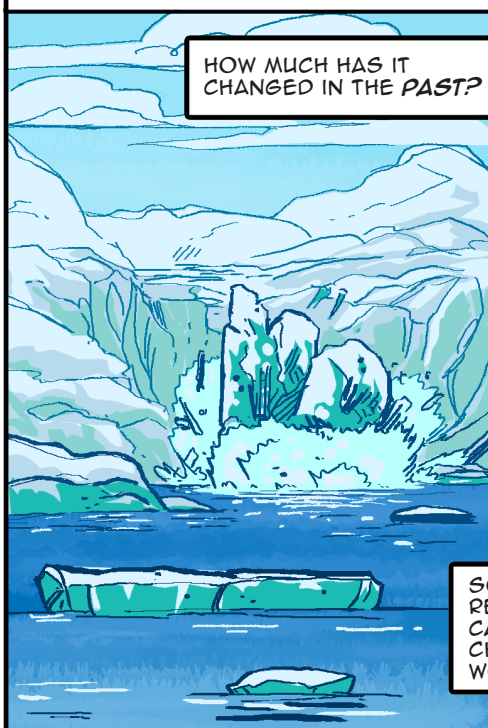


FIRES AND DROUGHTS WERE BECOMING MORE FREQUENT AND STORMS UNPREDICTABLE ALL AROUND THE WARMING PLANET.



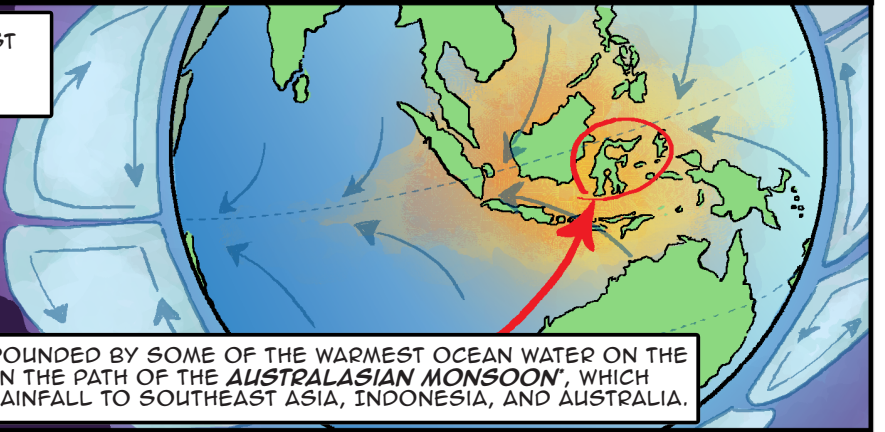
WINTERS IN THE MOUNTAINS WEREN'T LIKE THEY USED TO BE. SHE WONDERED WHAT THIS MEANT, AS THE FAMILIAR WAS STARTING TO BECOME UNFAMILIAR. HOW MUCH WILL THE WORLD CHANGE?

HOW MUCH HAS IT CHANGED IN THE PAST?



SO, SHE BECAME A **SCIENTIST** AND RETURNED TO THE MOUNTAINS AND CAVES TO TRY TO UNDERSTAND THE CHANGES HAPPENING AROUND THE WORLD.

IN SEARCH OF ANSWERS, OUR SCIENTIST WENT TO **SULAWESI**, AN **INDONESIAN ISLAND NEAR THE EQUATOR**.



SULAWESI IS SURROUNDED BY SOME OF THE WARMEST OCEAN WATER ON THE PLANET AND SITS IN THE PATH OF THE **AUSTRALASIAN MONSOON**, WHICH BRINGS CRITICAL RAINFALL TO SOUTHEAST ASIA, INDONESIA, AND AUSTRALIA.

THE COLLISION OF WARM WATER, THE MONSOON, AND OTHER LARGE WEATHER SYSTEMS, PRODUCES HUGE AMOUNTS OF ENERGY AND **TRANSPORTS HEAT** AROUND THE EARTH.

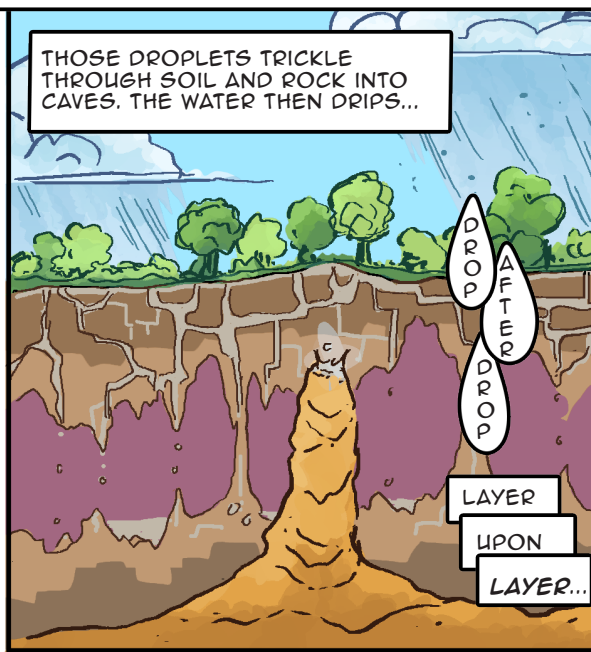
TO PREPARE FOR THE EFFECTS OF FUTURE CLIMATE CHANGE, OUR SCIENTIST WANTS TO LEARN WHAT THIS MONSOON WAS LIKE DURING **PAST WARM PERIODS**.

LUCKILY, THERE ARE **ANCIENT ROCKS WITH CODED MEMORIES** THAT CAN TELL US ABOUT THEIR PAST.

MONSOON RAIN CARRIES A MESSAGE IN EACH WATER DROPLET.



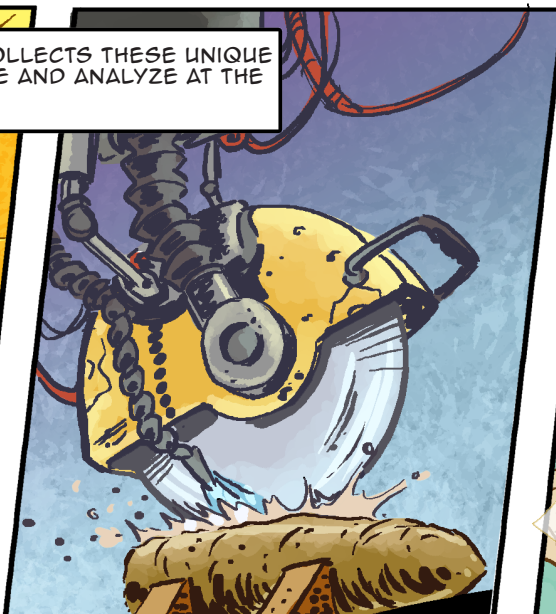
THOSE DROPLETS TRICKLE THROUGH SOIL AND ROCK INTO CAVES. THE WATER THEN DRIPS...



AND FORMS A **STALAGMITE**.



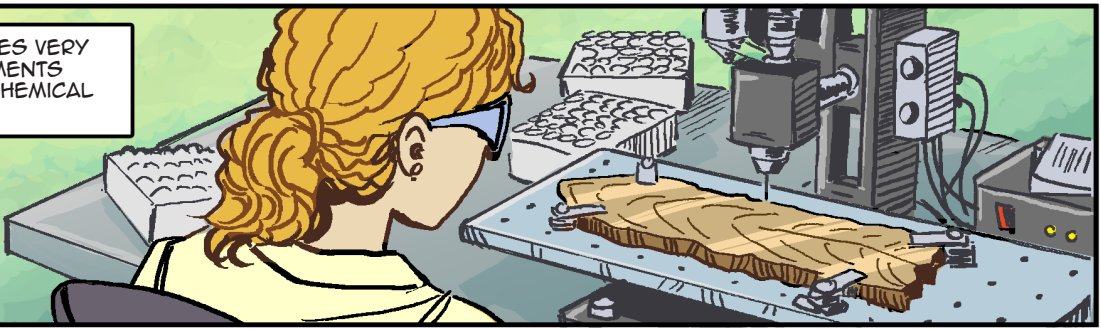
OUR SCIENTIST CAREFULLY COLLECTS THESE UNIQUE CLIMATE ARCHIVES TO DECODE AND ANALYZE AT THE LABORATORY.



USING **URANIUM-THORIUM DATING**, WE KNOW THAT STALAGMITES CAN BE OVER 500,000 YEARS OLD. THIS MAKES IT POSSIBLE TO LEARN HOW THE MONSOON CHANGED AS THE EARTH SWUNG BETWEEN EXTREMELY COLD AND WARM PERIODS, KNOWN AS **GLACIAL-INTERGLACIAL CYCLES**.

TO ISOLATE BRIEF SNAPSHOTS OF TIME, TINY SAMPLES ARE CAREFULLY DRILLED OUT ALONG THE CENTRAL LINE OF GROWTH. THESE FINE POWDERS CONTAIN A **CHEMICAL IMPRINT** OF THE WATER DROPLETS THAT FED THE STALAGMITE.

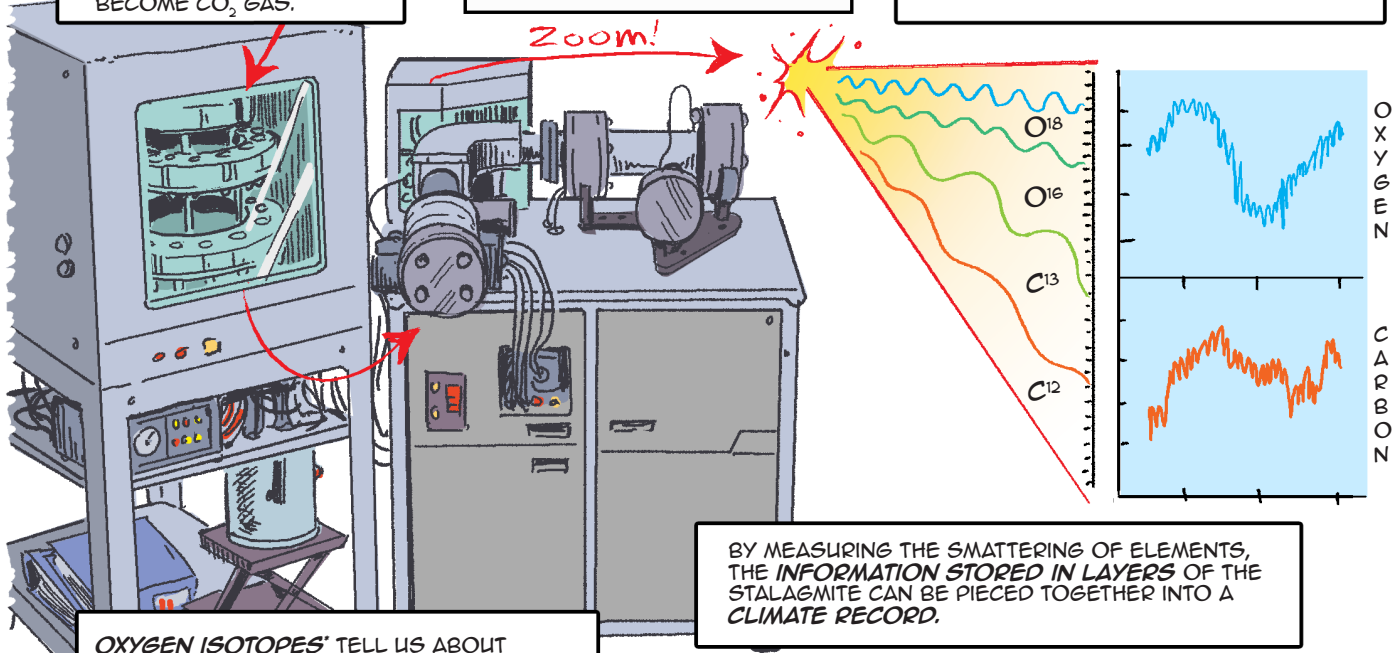
OUR SCIENTIST USES VERY SENSITIVE INSTRUMENTS TO EXTRACT THIS CHEMICAL INFORMATION.



**1** THE STALAGMITE POWDERS ARE DISSOLVED IN PHOSPHORIC ACID AND BECOME CO<sub>2</sub> GAS.

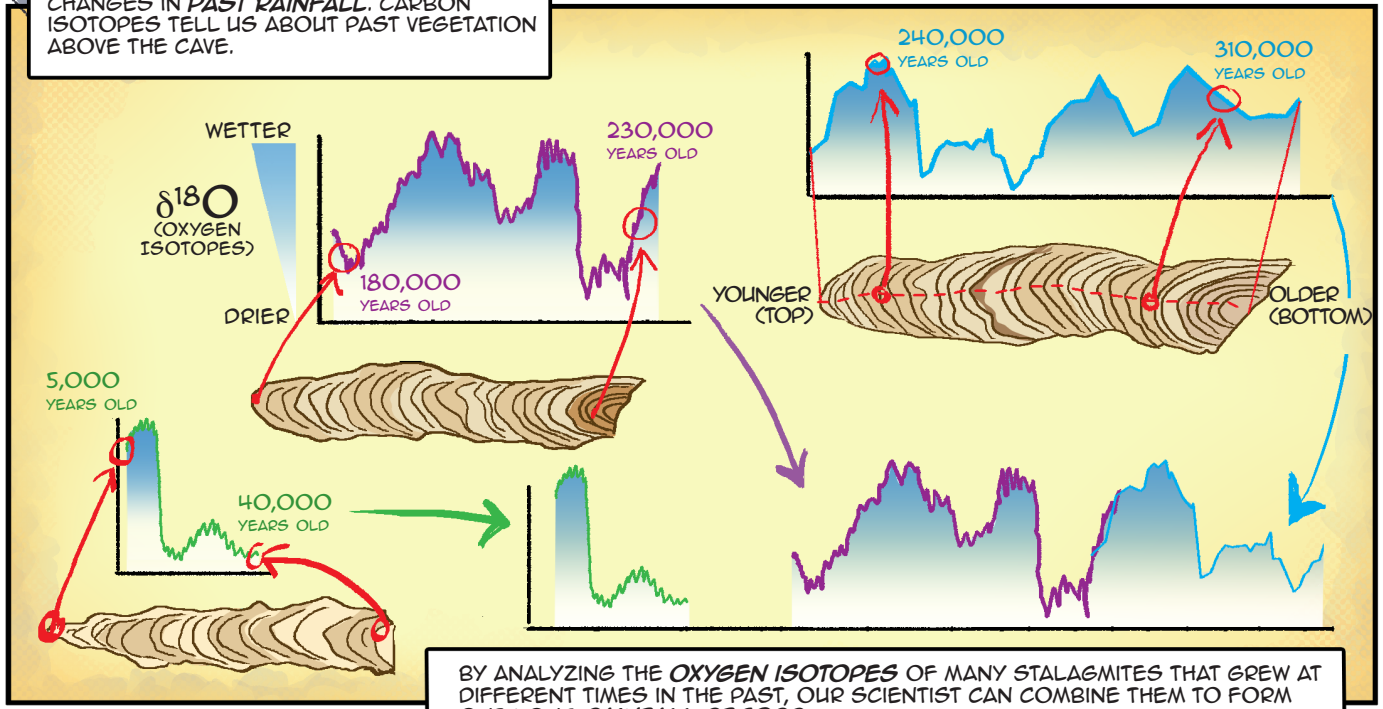
**2** POWERFUL MAGNETS IN THE MASS SPECTROMETER ARE THEN USED TO ACCELERATE THE CO<sub>2</sub> GAS AROUND A CURVE, CAUSING THE MOLECULES TO SEPARATE INTO SMALLER PARTS.

**3** AS THE ELEMENTAL COMPONENTS ZIP THROUGH THE MAGNET, THEY FAN OUT ACCORDING TO **WEIGHT** (NUMBER OF NEUTRONS) AND SLAM INTO A COLLECTION WALL AT THE OTHER END OF THE MASS SPECTROMETER.



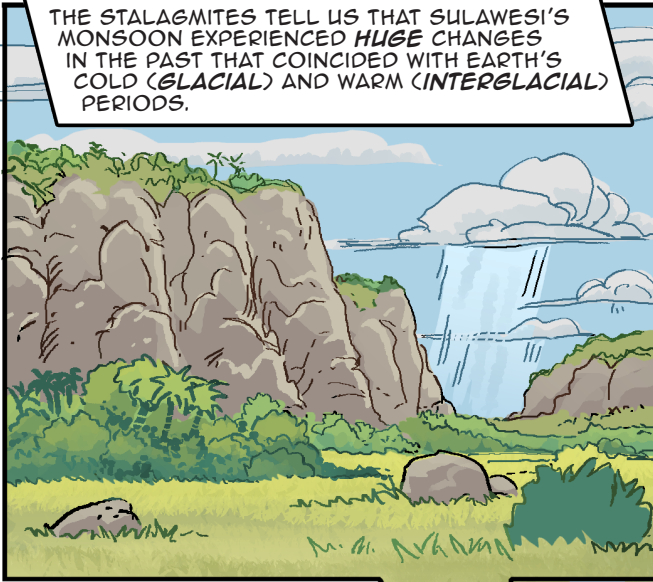
BY MEASURING THE SMATTERING OF ELEMENTS, THE **INFORMATION STORED IN LAYERS** OF THE STALAGMITE CAN BE PIECED TOGETHER INTO A **CLIMATE RECORD**.

**OXYGEN ISOTOPES** TELL US ABOUT CHANGES IN **PAST RAINFALL**. **CARBON ISOTOPES** TELL US ABOUT PAST VEGETATION ABOVE THE CAVE.

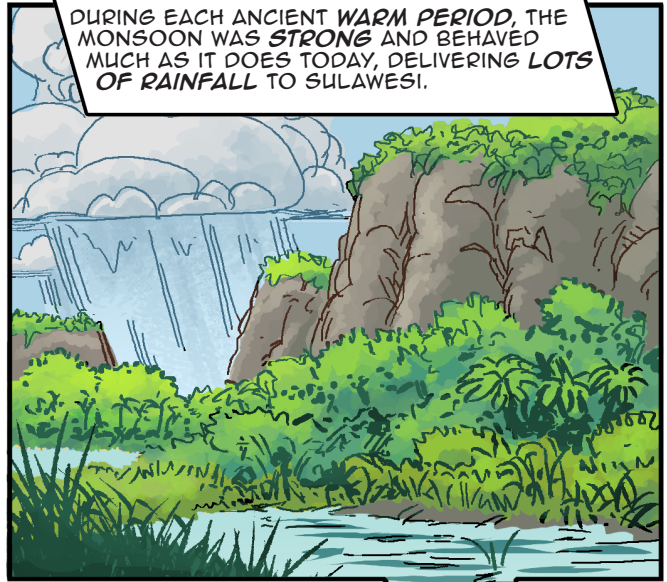


BY ANALYZING THE **OXYGEN ISOTOPES** OF MANY STALAGMITES THAT GREW AT DIFFERENT TIMES IN THE PAST, OUR SCIENTIST CAN COMBINE THEM TO FORM ONE LONG **RAINFALL RECORD**.

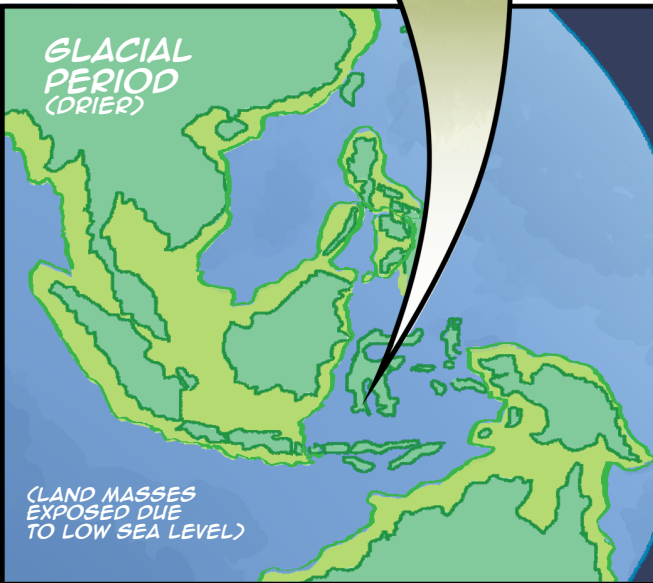
THE STALAGMITES TELL US THAT SULAWESI'S MONSOON EXPERIENCED **HUGE** CHANGES IN THE PAST THAT COINCIDED WITH EARTH'S COLD (GLACIAL) AND WARM (INTERGLACIAL) PERIODS.



DURING EACH ANCIENT **WARM PERIOD**, THE MONSOON WAS **STRONG** AND BEHAVED MUCH AS IT DOES TODAY, DELIVERING **LOTS OF RAINFALL** TO SULAWESI.

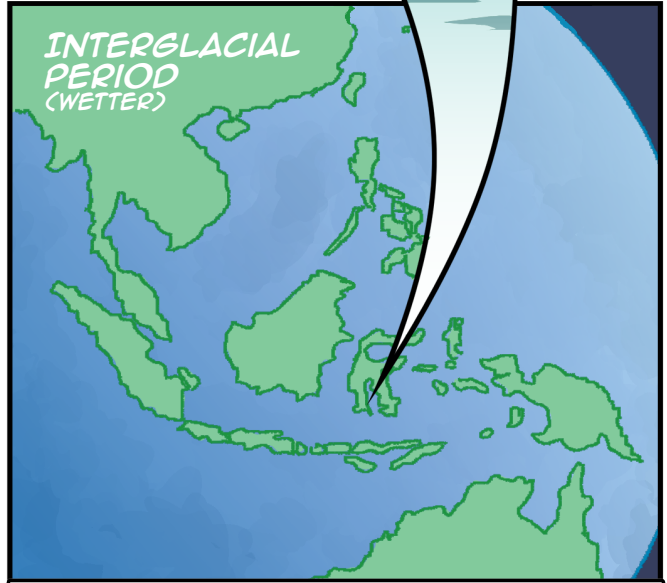


**GLACIAL PERIOD (DRIER)**



(LAND MASSES EXPOSED DUE TO LOW SEA LEVEL)

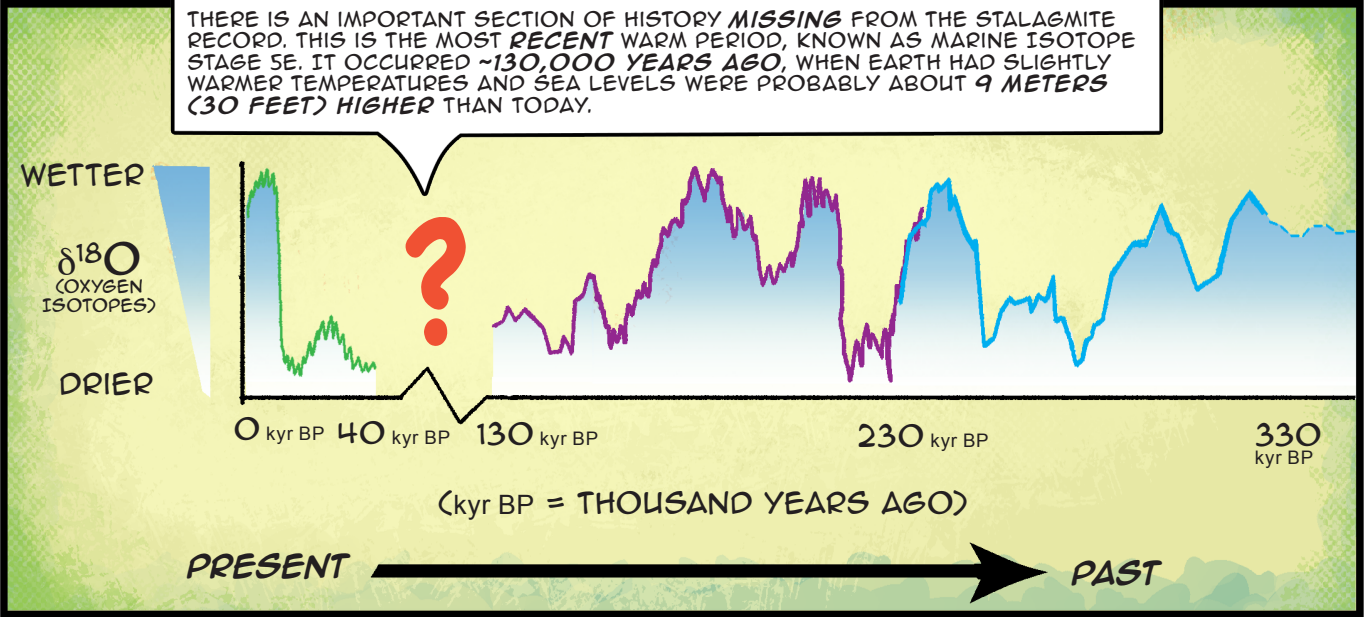
**INTERGLACIAL PERIOD (WETTER)**



IN BETWEEN EACH WARM PHASE IS A LONG COLD **GLACIAL PERIOD**. THE MONSOON WAS MUCH **WEAKER** AND SULAWESI WAS MUCH **DRIER** THAN IT IS TODAY.

THIS CONSISTENT PATTERN OF **DRY AND WET CYCLES** GIVES US IMPORTANT INFORMATION ABOUT HOW **EXTREME** THE MONSOON CAN BE... BUT SULAWESI STUMPS OUR SCIENTIST WITH A **NEW MYSTERY**.

THERE IS AN IMPORTANT SECTION OF HISTORY **MISSING** FROM THE STALAGMITE RECORD. THIS IS THE MOST **RECENT** WARM PERIOD, KNOWN AS MARINE ISOTOPE STAGE 5E. IT OCCURRED **~130,000 YEARS AGO**, WHEN EARTH HAD SLIGHTLY WARMER TEMPERATURES AND SEA LEVELS WERE PROBABLY ABOUT **9 METERS (30 FEET) HIGHER** THAN TODAY.



WETTER

$\delta^{18}O$  (OXYGEN ISOTOPES)

DRIER

0 kyr BP

40 kyr BP

130 kyr BP

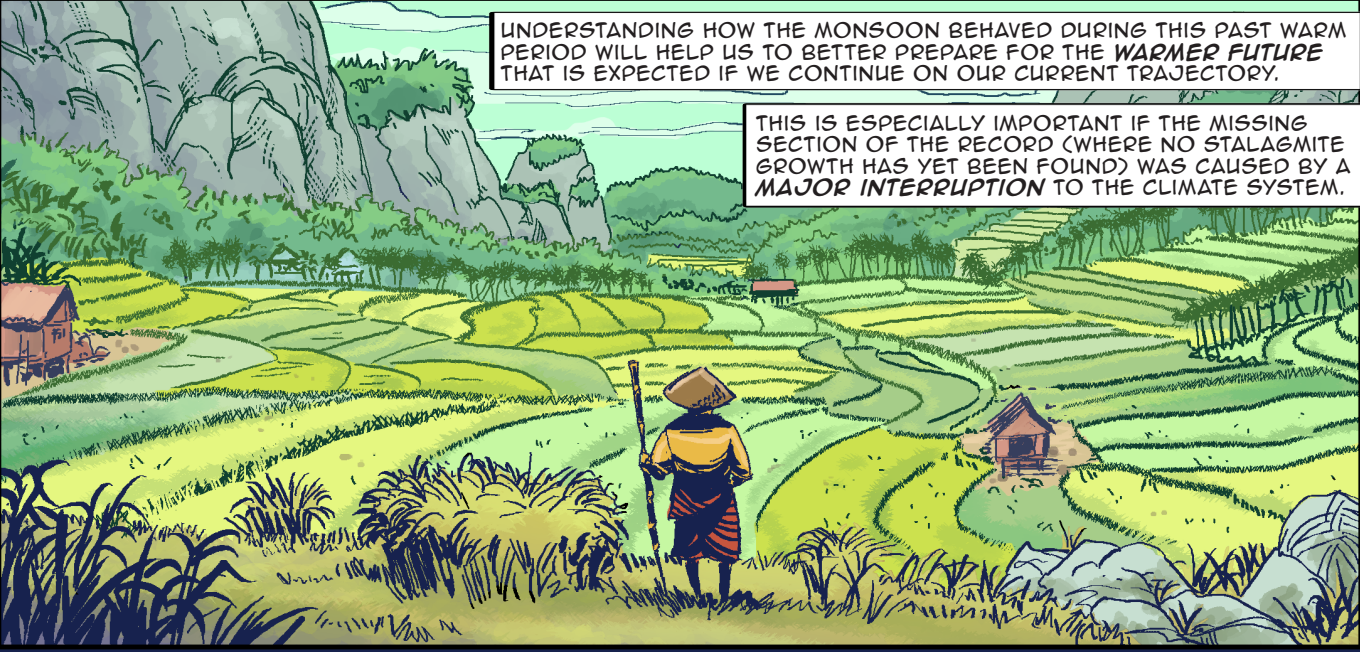
230 kyr BP

330 kyr BP

(kyr BP = THOUSAND YEARS AGO)

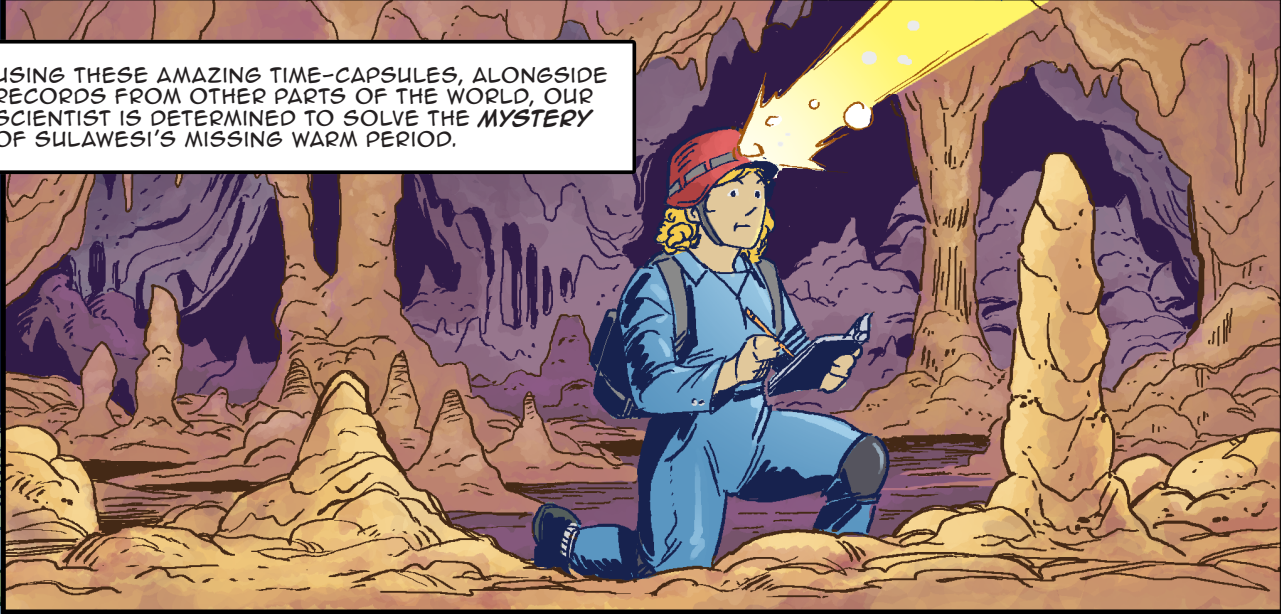
PRESENT

PAST



UNDERSTANDING HOW THE MONSOON BEHAVED DURING THIS PAST WARM PERIOD WILL HELP US TO BETTER PREPARE FOR THE **WARMER FUTURE** THAT IS EXPECTED IF WE CONTINUE ON OUR CURRENT TRAJECTORY.

THIS IS ESPECIALLY IMPORTANT IF THE MISSING SECTION OF THE RECORD (WHERE NO STALAGMITE GROWTH HAS YET BEEN FOUND) WAS CAUSED BY A **MAJOR INTERRUPTION** TO THE CLIMATE SYSTEM.



USING THESE AMAZING TIME-CAPSULES, ALONGSIDE RECORDS FROM OTHER PARTS OF THE WORLD, OUR SCIENTIST IS DETERMINED TO SOLVE THE **MYSTERY** OF SULAWESI'S MISSING WARM PERIOD.



THIS STORY OF OUR SCIENTIST REMINDS US TO BE **CURIOUS** AND **ASK QUESTIONS**. THE NATURAL WORLD HAS A LOT TO SAY.

We are eternally grateful to the Australian Research Council for past and current funding (e.g. ARCDP180103762). There is a large research team behind this work and we acknowledge the enormous contributions from Mike Gagan, Gavin Dunbar, and Claire Krause. We are indebted to Baharudin (of Konservasi Sumber Daya Alam), our colleagues at the Research Center for Geotechnology, Indonesian Institute of Sciences (LIPI), and the staff of Bantimurung-Bulusaraung National Park (with special thanks to Syaiful Fajrin). We thank Hamdi Rifai for field assistance and translating the comic into Bahasa Indonesia.

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