Soil Judging New Zealand

2024 MOANA OCEANIA SOIL JUDGING COMPETITON

New Zealand Society of Soil Science

SOIL SCIENCE AUSTRALIA

Joint NZSSS and SSA Competition

29th November to 1st December 2024, Rotorua, New Zealand

HANDBOOK

PLATINUM SPONSOR

Manaaki Whenua
Landcare Research

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2024 Moana Oceania Soil Judging Competition Handbook

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Event Organising Committee


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Expert Guests

Chief Judge

Scott Fraser
Senior Pedologist
Manaaki Whenua – Landcare Research

Professional Bio

I have a BSc, MSc, and PhD from UoW mostly focused on Biology and Soils. I completed a PhD in 2007 looking at the fate and effects of pulp mill waste applied to land. In 2007 I started work at Landcare Research as a consultant with CarbNZero and in 2009 moved to the Soils and Landscapes team as a pedologist/soil researcher. I've been involved with many projects since then including areas such as soil C monitoring, SQ, soil nutrients, LUC, peatlands and hydric soils. For the last 10 years I've mostly been involved with S-map work, in particular field soil survey and developing digital soil mapping techniques. I've led the BOP S-map Programme from 2020 to present. In the same year I started a part time consultancy in soils and LUC.

Scott's Thoughts on Field Soil Skills & Knowledge

Pedology is very much a field-based science, and there are many skills required to become a good pedologist, including understanding soil development, geology, geomorphology, and geochemistry, to name a few. Knowledge of soil genesis and soil properties is fundamental to the work I do in pedology. GIS and the ability to interpret maps are also essential skills, as well as strong communication abilities—being able to communicate effectively with a wide range of stakeholders such as farmers, land managers, scientists, and council staff is crucial. Currently, one of the biggest challenges in soil assessment and management is funding. Another challenge has been providing relevant soil information to a wide range of end users in an appropriate format. Since COVID, staff shortages have also posed significant difficulties, but looking ahead, this may improve over the next couple of years. Despite these challenges, I feel very privileged to have been able to work in this area for the past 15 years.

Scott’s Advice for Future & Current Soil Professionals:

Be observant, have an eye for detail, stay open minded – being a pedologist is a bit like being a detective

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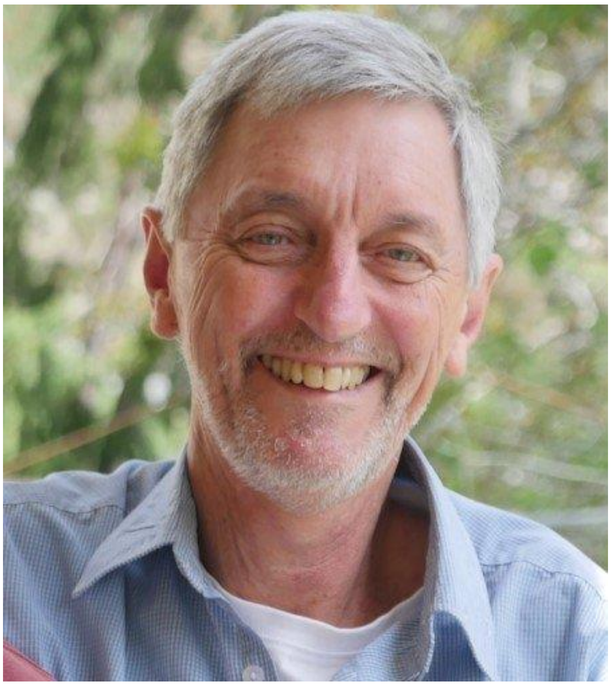
Geomorphology Expert



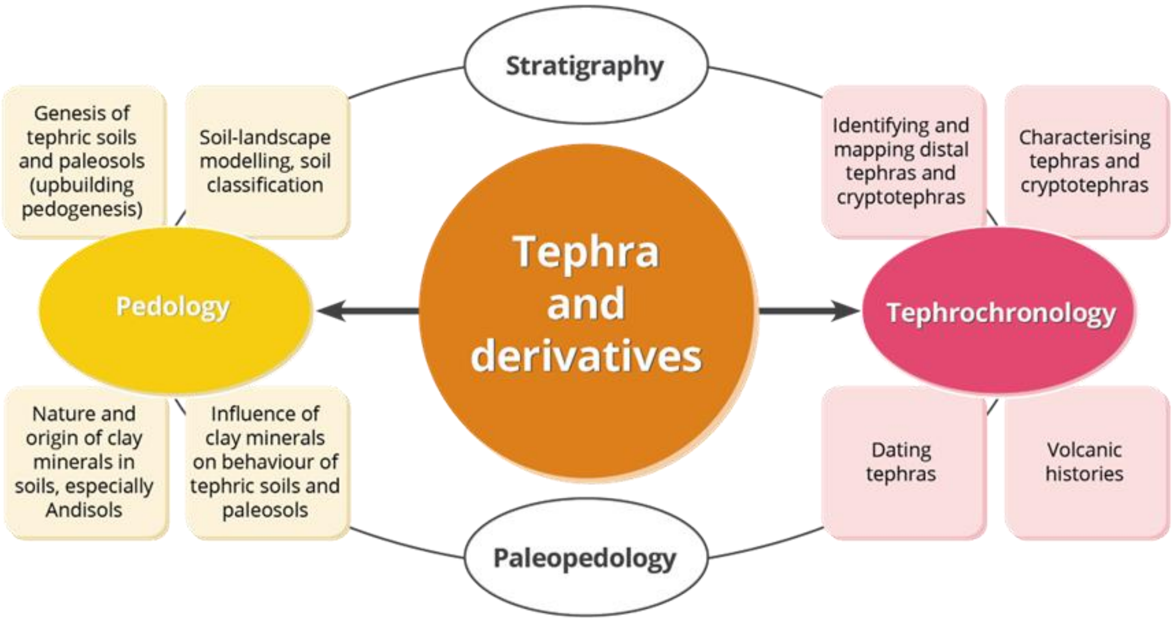
David Lowe
Honorary Professor
Earth Sciences, School of Science
Te Aka Mātuatua
University of Waikato
(retired in mid-June 2024)

Professional Bio

- Earned three degrees (BSc, MSc, PhD) from the Department of Earth Sciences, University of Waikato, during the 1970s and 1980s.
- MSc thesis focused on the origin and composite nature of tephra-derived soils in central Waikato region (pedology/paleopedology).
- PhD thesis centred on identifying, characterising, dating, and mapping distal tephras in northern New Zealand using peat and lake sediment archives (tephrochronology).
- Taught in the Department of Earth Sciences, University of Waikato, for approximately 42.5 years, progressing from junior lecturer to professor, including chairing the department from 2012-2014.
- Taught across a dozen BSc and MSc Earth Sciences courses (years 1 to 4), all involving field trips.
- Supervised or co-supervised 80 graduates and postgraduates to completion (chief supervisor for around half), including 22 PhDs, 51 MScs, 3 BSc (Hons), and 4 PGDips.
- Three pivotal 'holiday' jobs in the mid-to-late 1970s influenced his later career: (i) synthesising benzene from carbon samples in the fledgling radiocarbon dating lab at Waikato (1975-76), (ii) conducting soil descriptions in the tephra-draped eastern Waikato region for Soil Bureau, DSIR (Hamilton) (1976-77), and (iii) sledging (man-hauling) and mapping in the Britannia Range, Antarctica (1978-79).

Research:

- Focused on studying and utilising volcanic ash or tephra layers (from the Greek 'tephra', meaning 'ash' or 'ashes') produced by explosive volcanic eruptions. Tephras serve as marker beds with identical ages (those of the eruptions that generated them) wherever they are found, allowing tephrochronology to precisely link, synchronise, and date geological, paleoclimatic, soil, and archaeological sequences or events across different locations
- Specialised in pedology, the study of soils within the landscape, with a focus on tephra-derived soils and buried soils/paleosols, which have remarkable properties and behaviour due to their distinctive composition. Soil stratigraphy (or pedostratigraphy) connects these two discipline, as shown in the diagram below:



- As well as his core specialties, David has many other interests in the geosciences such as volcanology, paleoenvironmental studies including paleolimnology, clay mineralogy, archaeology, dating, and geoscience history

Significant achievements:

- Finds great satisfaction in teaching, particularly in mentoring graduates and postgraduates, supporting their research, and seeing their future successes. Mentoring early-career researchers (ECRs) and graduates has been especially fulfilling.
- Actively contributes to soil science in New Zealand in various ways, including encouraging students in the discipline, leading and supporting field trips and conference activities, and contributing similarly to global tephra studies through activities of 'Commission on Tephrochronology' for many years

- Enjoys collaborations with CRI staff, especially Scion/Forest Research (supporting several student research projects), GNS Science, Manaaki Whenua – Landcare Research, and with staff and students from other research organisations, universities, regional councils, and private companies.
- Proud to have co-authored the textbook *The Soils of Aotearoa New Zealand* (Hewitt, Balks, Lowe, 2021, Springer), which received awards in both Australia and New Zealand.
- Great thrill to have conducted research and connected with wonderful people in many places, including in CSIRO (Adelaide, 10 months leave), Antarctica, Yukon Territory, Japan, UK, etc.

Many research highlights with colleagues and students including:

- Mapping, identifying, and dating distal tephras and cryptotephras in northern New Zealand and relating such deposits to associated upbuilding soils and paleosols
- Contributing to understanding of past environmental change in NZ through collaborative research projects involving bogs and lakes
- Co-developing a new method for extracting ancient DNA from buried allophanic soils on Holocene tephras (Marsden project)
- Identifying Andisols (Andic Chernic Tenosols in ASC, equivalent to Allophanic Soils in NZSC) in southeast South Australia (on mid-Holocene Mt Gambier and Mt Schank tephras)
- Co-developing a new method for working out past earthquake history (location, timing, magnitude) of the central Waikato region using spatial and temporal distribution of liquefied tephra layers in lakes, CT imaging, and other techniques (Marsden project)

David’s Thoughts on Field Soil Skills & Knowledge

I strongly agree with Dr Roy W. Simonson (1957):

> “Soils are overlooked and undervalued as intrinsic and essential components of terrestrial ecosystems. They can be used as environmental indicators because they integrate the lithosphere, the biosphere, the hydrosphere, and the atmosphere, through the course of time: the profile carries within itself a record of its history for those who learn to read it. **The “book of soils” should be on the required reading list for all earth scientists!”**

Prof Henry Lin (2007) observed:

> “A crushed soil sample is as akin to a natural soil profile as a bulk of ground beef is to a living cow”.

Hence, the ability to ‘read’ and understand a soil profile is essential attributes for all soil scientists to help interpret their research and support land management. By considering the profile and setting (site characteristics), soil scientists can:

- Identify similarities and differences between soils, enabling meaningful comparisons.
- Classify soils, summarising key properties and likely responses to various land management activities, thus guiding practical treatment or management.
- Establish a foundation for systematic sampling for analysis and research.
- Interpret the historical environment of a site, as the soil profile serves as a "memory bank" of its paleoenvironment.

David’s Advice for Future & Current Soil Professionals:

- Develop a strong foundation in geosciences, soils, landscapes, and past environments, as pedologists are integrators.
- Understand the differences between geological layering (and geological processes) and soil horizonation (and pedological processes), especially in layered landscapes like tephra or loess accumulation areas. Discussed in section 2.1 of this handbook (Horizon designations).
- Recognise that careful, accurate soil horizonation is often the most critical part of a profile description, particularly in layered profiles where upbuilding pedogenesis occurs.
- Understand the difference between topdown pedogenesis and upbuilding (retardant, developmental) pedogenesis
- Be mindful of mapping scale limitations and understand the distinction between mapping scale and visualisation scale in digital contexts.
- In terrains where loess and thin distal tephras are deposited incrementally at slow rates of accumulation (about 5-20 mm per century), appreciate that every part of an upbuilding soil profile has served as a topsoil (A horizon) at some point. Consequently, the profile’s fabric reflects temporary, surface-driven soil processes.
- Consider gaining experience in farm-scale soil mapping and Land Use Capability (LUC) mapping (or similar) and develop the ability to apply the national soil classification (NZSC).

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Land Use Capability Expert

Simon Stokes

Director/Consultant
Simon Stokes Consulting Limited
Member of NZ Soil Science Society, NZ Assn of Resource Management, NZ Grasslands Assn, NZ Institute of Forestry

Simons Thoughts on Field Soil Skills & Knowledge

Soil knowledge is fundamental to the successful care and management of Aotearoa/New Zealand's environment. Our soils are deeply embedded in Te Ao Māori—our indigenous people's way of life and worldview. It has been a cornerstone of my work for 30 years, and probably longer, when I think back to the adventures in the deep gullies on the farm and the numerous post holes I dug. Soil is also something that consistently grabs the attention and interest of farmers and growers when working with them on soil care and management.

Over many years of fieldwork, I've noticed a pattern: when a workshop or discussion is held on environmental management, the thing that sparks the most enthusiasm is often an activity related to soil. And yet, it's a subject we tend to leave until last or push aside because it seems too complicated. When we do that, our work becomes less accurate and less impactful, as we end up generalising about the paddock or farm, simplifying the knowledge into a soil order for a modelling programme. On a farm or orchard scale, that just doesn't work for the farmer or grower—they need accuracy more than ever. In reality, the variations in soil at a location, their different uses and management needs, and their capabilities or limitations must be considered.

If we want to improve how we care for and manage our soils, we need to remind ourselves to feel them under our boots, to see their landscape setting, and to understand their life. Growing your soil knowledge never stops – and that's the beauty of every hole dug or profile created: there's always something new to discover. Learning doesn't have to be complicated. The early New Zealand Soil Surveys are incredibly thorough investigations of our soils, complete with detailed maps. There are also a number of easy-to-read books on soils, like Soils in the New Zealand Landscape – The Living Mantle by Les Molloy. Once you understand the fundamentals of soils – how they're characterised, analysed, and categorised – and you've had plenty of hands-on experience, it becomes a lot more fun and far more accurate than just relying on spatial data on a computer.

The Visual Soil Assessment, developed by Dr. Graham Shepherd, was transformational for those of us working with farmers and growers, and it's a must-use tool. What concerns me, however, is that while technology is improving how we analyse and field-map soils and the landscape, it is also distancing us from the soil itself. We don't have to survey exactly as they did in the early 20th century, but we still need to walk the land. I'm deeply concerned about people providing soil maps or information based purely on spatial models without fully understanding what they are presenting. Those who work the land want that connection under their boots – we can't let technology remove that ability to connect the farmer or grower with the soil. It's a partnership and a relationship. To lose that context would be like calling soil 'dirt' and ignoring its vitality and life. It's also not the Aotearoa/New Zealand way of doing things.

Simons Advice for Future & Current Soil Professionals:

Buy a spade and use it. Buy an auger and use it. Get out into the landscape as often as possible – fossick, dig holes, and scrape a bank profile. It's the forensic nature of understanding soils, their landscape, and geomorphological setting that makes it both exciting and essential if you want to truly share or advise to the best of your ability and knowledge. Aotearoa's soils are unique to us and to our indigenous people – both have evolved in sync over time. Try to understand how that relationship exists within the context of your role and those you work with, and grow an understanding that is both complementary and respectful, shaping how we manage soils in the future. Soils aren't just there for us to use; they need to be cared for with a uniquely Aotearoan perspective.

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Event Support Team

Chief Event Marshals

Julie Gillespie,
Lincoln University

Xueying (Sherry) Che,
Lincoln University

Site Managers, Roaming Coaches, Event Marshals, Media, First Aid & Other Event Volunteers

Sheree Balvert
Errol Balks
Megan Balks
Maddison Bingham
Cady Burns
Sam Carrick
Kirstin Deuss
Lauren Eyre
Maya Greet
Leo Greyling
Lloyd Humphrey
Abigail Jenkins
Josie Mazzetto
Piper McElrea
Marita McGuirk
Emily McKay
Josh Nelson
Ivanah Oliver
Veronica Penny (Lead Field Coordinator)
Louis Ravanat
Alistair Ritchie
Jessie Ross
Pierre Roudier
Carol Smith
Sonia Thompson
Jonathan Walton
Naomi Wells

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New Zealand Society of Soil Science

SOIL SCIENCE AUSTRALIA

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2024 Participating Organisations

Universities:

- Australian National University
- Central Queensland University
- Curtin University
- Fiji National University
- La Trobe University
- Lincoln University
- Massey University
- Monash University
- Royal Melbourne Institute of Technology
- Soil Food Web School Oregon
- Southern Cross University
- The University of the South Pacific
- Tonga National University
- University of Adelaide
- University of Canterbury
- University of New England
- University of Queensland
- University of South Australia
- University of Southern Queensland
- University of Sydney
- University of Tasmania
- University of Western Australia
- Waikato University

Regional Councils:

- Environment Canterbury
- Hawke's Bay Regional Council
- Marlborough District Council
- Northland Regional Council
- Otago Regional Council
- Taranaki Regional Council
- Tasman District Council
- Toi Moana Bay of Plenty Regional Council
- Waikato Regional Council

Consultancies:

- Babbage Consultants
- Hanmore Land Management Ltd
- Landloch Pty Ltd
- Sarah Dudin Consulting
- Simon Stokes Consulting
- Terra Pura Consulting Limited

Research Institutes and Societies:

- AgResearch
- CSIRO
- Manaaki Whenua - Landcare Research
- Pacific Community (SPC)
- Scion
- South Australian Research and Development Institute
- SSA (Queensland branch)
- SSA (South Australian branch)
- SSA (Western Australian branch)
- Tasmanian Institute of Agriculture
- TERN
- Young in Soil and Earth Science Society

Other Organisations and Ministries:

- Department of Agriculture and Rural Development (Vanuatu)
- Department of Agriculture (Tuvalu)
- Hills and Fleurieu Landscape Board
- Live & Learn Environmental Education
- Ministry of Agriculture, Food and Forests (Tonga)
- Ministry of Environment, Lands and Agriculture Developments (Republic of Kiribati)
- MORDI Tonga Trust

Tag Your Social Media Post

Get involved and capture the excitement at this year's Joint Australia-New Zealand Soil Judging Competition! We invite all participants to share their best moments on social media. To have your photos featured and celebrate our shared passion for soil science, you'll need to use the hashtag below and **tag us** on one of our official social media accounts. Whether it's soil profiles, team shots, or on-site fun, we want to see it all!

#SoilJudgingAusNZ

@NZSoilSciSoc
AND
@soilscienceaust

@NZ Society of Soil Science
AND
@Soil Science Australia

@NZSoilSciSoc
AND
@soilscienceaust

@SoilScienceAust

PRIZES to be won for the most engaging and impactful social media post!

Join our Whatsapp Group

Please join the **2024 Moana Oceania Soil Judging Competition** WhatsApp group. This will be our main communication channel for the event.

We'll use it to share important information, such as:
- Details on the competition location and schedule
- Any last-minute changes or updates
- Reminders and other key notices

To help keep things organised we ask that all volunteers, as well as at least one member of each team, join the group. Ideally, one person per team (all coaches, or a team member in the absence of a coach) will be the point of contact for any questions. This will help reduce unnecessary messages in the group.

Please ensure that the person who joins the group has access to WhatsApp and can check it during the event days, even in areas without Wi-Fi. All communication over the three event days will be sent via this group.

Scan the QR code to join:

2024 Moana Oceania Soil
Judging Competition
WhatsApp group

Scan or upload this QR code using the WhatsApp
camera to join this group

Soil

Welcome

Kia ora koutou,

Welcome to the **2024 Moana Oceania Soil Judging Competition**, jointly hosted by the New Zealand Society of Soil Science (NZSSS) and Soil Science Australia (SSA) and held this year in the stunning volcanic landscape of Rotorua, New Zealand.

This prestigious competition has become a much-anticipated event on both of our Societies' calendars. This year's event provides an unparalleled opportunity to learn alongside participants from various soil-related backgrounds, including university students, regional council scientists, land managers, consultants, and general soil enthusiasts. Participants have travelled from every Australian state, across New Zealand and from a number of Pacific Island nations.

Soil judging is one of the best possible training grounds for aspiring soil professionals and those working professionals who wish to add a string to their bow of skills. Whether you have an interest in research, teaching, or consultancy, within academia, government or the private sector, there is no shortage of career possibilities in soils.

Students are our next generation of soil scientists and land managers and for that reason you play a critical role in both the NZSSS and SSA. Both nationally, and through our branches, our societies support students through a range of initiatives:

- Travel grants to attend the biennial national soil science conference.
- Financial support to attend the national soil judging competition and for the absolute best competitors, to attend the World Congress of Soil Science.
- Awards, presented at national conferences and by our branches.
- Reduced membership fees for our societies and registration fees for events.
- Great opportunities for mentoring and networking.

Over 3 days, we aim to equip participants with the soil description and classification skills that are vital for interpreting the best management and land use for any given soils. The practice and competition days will be intense, as your problem-solving skills, academic credentials and practical experience will be put to the test. This is your opportunity to show how much you have learned about soil description and classification and how you apply that knowledge in the field, often under pressure. Make the most of the training sessions, in the lead up to the competition day, and the chance to learn from some of our finest soil scientists as well as your fellow entrants.

Remember, beyond the technical challenges, you will also discover the value of ongoing education and professional development and the satisfaction that comes from strong teamwork. Most importantly, we hope this experience reinforces your commitment to sustainable land management and to protecting one of our nation's most precious natural assets - our soil.

Thank you to our volunteer organising committee, the NZSSS council, executive office of SSA and to all the sponsors, training staff, coaches and families who have supported the students and teams throughout the year.

We wish you all the best in this year’s competition and look forward to your involvement with NZSSS and SSA for many years to come.

Sam Carrick
President, New Zealand Society of Soil Science

Darren Kidd
President, Soil Science Australia

Foreword

Tēnā Koutou,

Welcome to the **2024 Moana Oceania Soil Judging Competition**, held in Rotorua, New Zealand, from 28 November to 1 December 2024! This event serves as an exciting prelude to **SOILS ROTORUA 2024** - the Joint New Zealand Society of Soil Science and Soil Science Australia Conference, "Te Kiri o Papatūānuku/ Weaving Soil Science Across Cultures and Events", scheduled for 2-5 December at the Rotorua Energy Events Centre.

This year's competition is the product of 18 months of dedicated planning, building on the experience and expertise of past organising committees from both New Zealand and Australia. We're fortunate to have had a dedicated organising committee and support from the SOILS ROTORUA 2024 conference team, all of whom have helped make this what we think may be the largest soil judging competition ever held worldwide! With over 200 participants, coaches, and volunteers from 20+ universities, nine regional councils, and more than 15 scientific and governmental organisations, societies, and consultancies across New Zealand, Australia and the Pacific Islands, this event promises an unparalleled experience for learning and networking in an engaging, hands-on environment.

Soil judging provides a wonderful opportunity for students and coaches alike to develop the skills of describing soil profiles, and then translating this into a basic land capability assessment. It is a highly effective way to build practical, field-based skills in a supportive atmosphere.

We would like to sincerely thank this year's sponsors, whose generous support has enabled the New Zealand Society of Soil Science and Soil Science Australia to host the 2024 Moana Oceania Soil Judging Competition on this impressive scale. We encourage all participants to acknowledge and promote these sponsors on social media throughout the event.

The competition includes two days of immersive training, which for many of you will be your first time in a soil pit. Most importantly, being an inductee into the 'Art and Science' of soil judging is not an impediment, as demonstrated in previous events where even first-time participants have excelled, sometimes achieving top placements on Competition Day. This is an opportunity to connect with experts, academics, students, land managers and consultants. For students, this event offers a glimpse into potential careers in research, teaching, consultancy, and various roles across academia, government, and the private sector.

As the event concludes, we hope you will find that this hands-on learning experience has enriched your understanding and boosted your confidence with soil science. We encourage you to share your experience with fellow students and colleagues, inspiring them to come along to the next Australian Soil Judging Competition in Armidale, NSW in November 2025.

We would also like to extend a special thank you to the Toot, Ford, and Beauth families, who have generously allowed us to use their land for the soil pits and competition activities - your support has made this event possible.

Associate Professor Carol Smith
Co-Convenor, Soil Judging Committee
Associate Professor, Lincoln University

Dr Kirstin Deuss
Co-Convenor, Soil Judging Committee
Soil Scientist, Manaaki Whenua – Landcare Research

Health and Safety

Your safety is our priority during this event. Please take a moment to review the following health and safety guidelines.

Please follow the instructions of the event marshals and remain within the designated areas around the pits.

Potential hazards at the sites include:

Hazard	Action
Uneven ground: • Trips and falls	Take care with footing. Wear sturdy footwear.
Long or wet grass: • Slips and falls • Hidden objects	Take care with footing. Wear sturdy footwear.
Sun exposure: • Heat stroke • Sun stroke • Dehydration • Sunburn	Drink water. Utilise shade provided.
Cold exposure: • Hypothermia • General cold	Wear warm gear. Waterproof jacket.
Dust exposure when sieving soil	Sieve soil in well ventilated areas.
Wind: • Flying debris	Take care with loose objects if wind increases
Contact with plants: • Minor irritations e.g. nettle	Wash exposed skin. Antihistamines.
Contact with insects: • Potential allergens e.g. bees	Inform pit monitor if allergic to bees/wasps. Carry epipen.
Sharp tools: • Cuts when using niwashi's, spades etc.	Take care using tools.

All of the SJC sites are on working farms. Place any rubbish in the bins provided. Please give way to any farm machinery that may be moving about while you are on farm. In particular, please be aware of:

- Moving machinery, including quad bikes and tractors
- Stock, including cattle and sheep
- Farm dogs
- Electric fences

Please maintain a safe distance from the edges of pits and cuttings, as they present significant hazards. Close proximity to the edge increases the risk of falls and potential wall collapse, which could endanger individuals positioned below the exposure wall.

Geothermal activity
Although none of the Soil Judging Competition locations are situated in geothermally active areas, the broader Rotorua region is located within a volcanic zone. The likelihood of geothermal activity at any event site is extremely low. However, in the unlikely event of a natural disaster, please adhere to the instructions provided by the event marshals at your location.

Personal Protective Equipment (PPE)
Weather conditions can change rapidly, so always be prepared for cold or wet weather, even if the current conditions are good.

Please bring the following PPE with you on all practice and competition days.

- Sun hat
- Sunscreen
- Water bottle
- Warm jersey
- Wet weather gear
- Sturdy, enclosed footwear

Mobile Network Coverage
Cell phone connectivity may be poor in some event locations. Please speak to an event marshal if you need to get an urgent message out and you have no cell phone service.

First Aid
An appropriate first aid kit will be available at all event sites. There will be a first aid officer at each site and several event marshals with first aid training.

Emergency Plan
Event marshals will ensure site safety then provide first aid and seek emergency help. For police, fire, or ambulance, call 111.

Alcohol and Drugs
All persons engaged in field activities have a responsibility to ensure that they are not, through the consumption of alcohol or a drug, in a state that may endanger themselves or any other person.

Smoking
Please do not smoke at any of the event sites. Long grass is considered a fire risk in summer.

Participant Capability
Participants must be physically capable relative to the terrain and conditions likely to be encountered. Those with a medical condition which may require special consideration must inform an event or site manager. It is the responsibility of the participant to ensure the availability of the necessary medication(s). Other individual factors may also compromise

safety of the individual or group, and should similarly be notified to the organisers before departure. Personal capability may also change during the field trip, such as through exhaustion or injury. Significant loss of capability should be immediately notified to an event or site manager.

Contacts

Event Managers: Carol Smith (+64 21 106 9722) & Kirstin Deuss (+64 27 251 4752)
Site 1 Manager (Rerewhakaaitu): Emily McKay (+64 27 233 9801)
Site 2 Manager (Mamaku): Pierre Roudier (+64 22 315 6476)

First Aid Officer: Julie Gillespie (+64 22 083 0847)
First Aid Officer: Josh Nelson (+64 27 420 5755)

2024 MOSJC Timetable

Thursday 28th November 2024	
1800 - 2100	Welcome Function – Dinner included in registration fee. Eastwood Café, Rotorua. *(Located at Scion End of Titokorangi Drive / Long Mile Rd, access off Tarawera Road). Own transport or bus departs the Millennium Hotel, (1270 Hinemaru Street) at 5.45pm. Buses will be returning to the Millennium later in the evening.*

Friday 29th November 2024	
0700	Meet buses Site 1 Buses (12-seater) Site 2 Buses (50-seater) LOCATION 1 Pick up 7:00am Holdens Bay Holiday Park, 5 Stonebridge Park Drive LOCATION 2 Pick up 7:15am Arawa Park Hotel Rotorua, 272 Fenton Street LOCATION 3 Pick up 7:30am Millennium Hotel Rotorua, 1270 Hinemaru Street LOCATION 4 Pick up 7:45am Novotel Rotorua Lakeside, Lake End Tutanekai Street
0830	Buses arrive at field sites
0845	Day briefing
0900 - 1030	Practice Pit 1
1030 - 1130	Paramanawa | Morning Tea – Presentation by geomorphology expert at Site 1
1130 - 1300	Practice Pit 2
1300 - 1430	Kai tina | Lunch – Presentation by geomorphology expert at Site 2
1430 - 1600	Practice Pit 3
1600 - 1630	Summary and wrap-up of the day
1630	Buses depart for Rotorua
1730	Close of day

Saturday 30th November 2024	
0700	Meet buses Site 1 Buses (12-seater) Site 2 Buses (50-seater) LOCATION 1 Pick up 6:40am Holdens Bay Holiday Park, 5 Stonebridge Park Drive LOCATION 2 Pick up 7:15am Arawa Park Hotel Rotorua, 272 Fenton Street LOCATION 3 Pick up 7:30am Millennium Hotel Rotorua, 1270 Hinemaru Street LOCATION 4 Pick up 7:45am Novotel Rotorua Lakeside, Lake End Tutanekai Street
0830	Buses arrive at field sites
0845	Day briefing
0900 - 1030	Practice Pit 1
1030 - 1130	Paramanawa | Morning Tea – Presentation by Land Use Capability expert at Site 1
1130 - 1300	Practice Pit 2
1300 - 1430	Kai tina | Lunch – Presentation by Land Use Capability at Site 2
1430 - 1600	Practice Pit 3
1600 - 1630	Summary and wrap-up of the day
1630	Buses depart for Rotorua and Close of day
1930	Coaches Meeting - Good Eastern Taphouse, 279 Te Ngae Road, Rotorua

Sunday 31st November 2024	
0645	Meet buses Site 3 Buses (50-seater) LOCATION 1 Pick up 6:45am Holdens Bay Holiday Park, 5 Stonebridge Park Drive LOCATION 2 Pick up 7:00am Arawa Park Hotel Rotorua, 272 Fenton Street LOCATION 3 Pick up 7:15am Millennium Hotel Rotorua, 1270 Hinemaru Street LOCATION 4 Pick up 7:30am Novotel Rotorua Lakeside, Lake End Tutanekai Street
0800	Buses arrive at field sites
0820	Competition Day briefing
0840 - 0850	Transport to pits
0900 - 1015	Competition Rotation 1
1015 - 1045	Transfer between pits
1045- 1200	Competition Rotation 2
1200 - 1300	Kai tina | Lunch & Group Photos
1300 - 1415	Competition Rotation 3
1415 – 1445	Shuttle to next pit
1445 - 1600	Competition Rotation 4
1600 - 1630	Summary and wrap-up of the day
1630	Buses depart for Rotorua
1800	Pre-dinner drinks
1930 - 2030	Post Event dinner *Mac's Steakhouse, Rotorua*

Monday 26th June 2023	
07:30	Registration desk opens
08:45	Gather outside ready for Mihi
09:00	Mihi/Whakatau Welcome & Housekeeping
09:45	Paramanawa | Morning tea (kindly sponsored by CSIRO)
10:15	Plenary Speaker: Tanira Kingi
10:55	**2024 MOSJC Awards*** *Rotorua Energy Events Centre*
11:20	Plenary speaker: The Hon. Penelope Wensley
12:00	Kai tina | Lunch

*see page 28

2024 MOSJC Awards

Prize giving will be held on Monday, 2nd December 2024, at the Rotorua Energy Events Centre. **Please arrive by 10:00 am and be seated by 10:15**. The prize-giving session will be complemented by plenary speakers, both before and after, which are free for you to attend.

All soil judging participants are invited to attend the prizegiving ceremony. However, only those registered for the conference will have access to morning tea, lunch, and additional conference sessions. A special one-day conference rate is available on Monday for soil judging participants who wish to join these catered events and sessions.

The following awards will be presented:

University Team	Awarded to the university team with the highest team score
University Individual	Awarded to the university individual with the highest individual score
South Pacific Team*	Awarded to the South Pacific team* with the highest team score
Working Professionals Team	Awarded to the working professional team with the highest team score
Working Professionals Individual	Awarded to the working professional individual with the highest individual score
Bennison Family Trophy	Awarded to the Australian university team with the highest combined score from the two team soils pits and three highest individual scores.
Mikkat Trophy	Awarded to the Australian early career professional team with the highest combined score from the two team soils pits and three highest individual scores.
NZU Trophy	Awarded to the New Zealand University with the highest combined score from the two team soils pits and three highest individual scores.
NZWP Trophy	Awarded to the New Zealand Working Professionals team with the highest combined score from the two team soils pits and three highest individual scores.
Allan Hewitt Trophy	Awarded to the best overall New Zealand team (University or Working Professionals) with the highest combined score from the two team soils pits and three highest individual scores.
South Pacific Soil Judging Trophy**	Awarded to the best overall team (University or Working Professionals) from countries in the South Pacific Region with the highest combined score from the two team soils pits and three highest individual scores.

*This award goes to South Pacific Teams excluding New Zealand and Australia

**Eligible countries include Australia, Cook Islands, Fiji, Indonesia, Kiribati, Marshall Islands, Micronesia, Nauru, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, Vanuatu. This trophy is only awarded when at least two countries are represented.

Invitation to Join Soil Judging Feedback & Research

As part of this soil judging competition, we welcome your feedback on the event and invite you to participate in a research project titled **"Evaluating Student and Working Professionals' Attitudes and Learning at a Soil Judging Event."**

Purpose of the Research

The research aims to evaluate the impact of participation in a soil judging competition on the learning of soil-related skills and concepts, as well as on attitudes towards soil science. The findings will be used to enhance the delivery of future soil judging competitions and will contribute to a research publication in a peer-reviewed journal. Participation is entirely voluntary, and you are not obligated to take the survey.

How to Participate

The study involves completing two surveys – a **pre-survey** and a **post-survey** – administered via the Qualtrics platform, and accessible through QR codes.

- **Pre-Survey:** Available from **3:00 PM, Thursday, 21 November**, until **11:59 PM, 29 November (end of Day 1)**.
- **Post-Survey:** Available from **1:00 PM, Sunday, 1 December**, until **11:59 PM, 8 December**. This survey also includes an opportunity to provide feedback on the event.

A separate information and consent sheet will be included in your participant pack for further details.

Research Team

The research is being conducted by:

- **Carol Smith** (carol.smith@lincoln.ac.nz) and **Louisa Hall** (louisa.hall@lincoln.ac.nz) – Lincoln University
- **Ivanah Oliver** (ioliver4@une.edu.au) – University of New England, Armidale, Australia
- **Kirstin Deuss** (deussk@landcareresearch.co.nz) – Manaaki Whenua Landcare Research

We value your input and thank you for considering participation in this project. Your feedback is essential to improving future soil judging events.

Soil Judging Competition Rules

Team composition

A team is composed of between four and five members. Members of student teams must be enrolled in a university, college, polytechnic or similar institution at the time of enrolment. Working professionals may include anyone employed within industry, academia, government, council organisations, or self-employed individuals.

Competition day format

This Handbook may be used in the field along with the "Soil Description Handbook" (*Revised Edition*) (Milne et al., 1995) and the "New Zealand Soil Classification" *Third Edition* (Hewitt, 2010). Hand-held electronic devices (mobile phones, tablets etc.) are strictly prohibited at all times in the competition day profiles unless specified by the soil judging competition committee.

Calculators are permitted for use during the competition.

The event consists of two parts:

- Two consecutive days of practice at two locations each with three pits, cutting exposures, or soil cores, and
- A third 'competition' day comprising two team profiles and one individual profile.

For the practice days, your coach or nominated team leader will be supplied with completed scorecards so you can 'calibrate' your descriptions against the official descriptions. Pit monitors and expert pedologists will be present to assist on practice days.

On the competition day, your coach is not allowed to speak to, or assist you, in any way.

At each pit, a clearly outlined 'restricted area' is designated on the pit face to allow you to measure horizon depths and to determine boundary distinctness. A pit tape measure is attached to the restricted area for measurement purposes.

THE RESTRICTED AREA IS NOT TO BE DISTURBED IN ANY WAY!

This means you must not pick out or take samples or touch the restricted area at all. In fact, you should stay well away from the ribbons that delineate the restricted areas. Contestants who contravene this rule will have points removed from their scores and may be disqualified from the competition.

The pit ID, the depth of soil to be considered, the number of horizons to describe, pertinent chemical data, and other relevant information will be available at each pit. A nail or pin will be placed somewhere randomly in the 3rd horizon (unless specified differently on the pit information card).

Competitors may be assigned to a particular face within the pit (e.g. Team Pit 1, Left face). It is the competitor's responsibility to record this information on their scoresheet for the purpose of marking.

Slope stakes are placed along the grade (i.e. transverse to the contour) for determination of slope and site position.

Seventy-five minutes (1hr & 15min) will be allowed for both the team-judged and individually-judged profiles during competition day. A strict rotation policy will be implemented for the competition pits to ensure everyone has an equal and fair amount of time in front of the 'restricted area'. An example rotation schedule is presented in Table 1. Pit Monitors will manage rotations through the pits and will ensure competitors abide by the rules.

Talking is not permitted between competitors during the individual judging and Pit Masters have been instructed to collect scorecards from any offending competitors, who will then receive a score of zero for that profile. All competitors should show respect for one another and avoid creating distractions during the competition.

Table 1. Example pit rotation

Time (minutes)#	Team 1	Team 2	Team 3	Team 4
0-5	In*	Out	In	Out
5-10	Out	In	Out	In
10-15	In	Out	In	Out
15-20	Out	In	Out	In
20-30	In	Out	In	Out
30-40	Out	In	Out	In
40-50	In	Out	In	Out
50-60	Out	In	Out	In
60-75	---Free** ---------------------------------			

*In and out refer to competitors allowed in the pit or outside of the pit, respectively.
**During free time, all teams/competitors may have access to the pit.

Time allocation may vary based on the final number of participating teams.

Scoring & scoresheet

Scoresheet entries must be made according to the instructions for each feature to be judged (see following sections of the handbook). Only one response should be entered in each field, unless instructed otherwise. **Do not forget to appropriately deal with null entries**.

Scores will be tallied as indicated on the scoresheet for each participant and each team.

1. Site Characteristics

Refer to the chapter ‘Site Data’ in Milne et al. (1995) for full information on how to describe site characteristics.

For the competition, the following site characteristics have to be determined:

- 1.1 Slope gradient
- 1.2 Geomorphic position
    - 1.2.1 Landscape & landform
    - 1.2.2 Landform component or element
- 1.3 Parent material
- 1.4 Erosion & deposition
- 1.5 Vegetation cover

1.1 Slope gradient

Slope stakes are placed to indicate the transect over which the slope gradient needs to be determined. The competitors are responsible for checking the heights of the stakes are equal.

Use a clinometer to determine the ***slope gradient in degrees****. Use Table 2 to convert the slope degrees into a class code and record this code on the scoresheet.*

If a site falls on the boundary of two slope classes, mark the steeper class.

Table 2. Slope gradient class codes

CODE	DESCRIPTION	SLOPE (DEGREES)	GRADE (%) -UPPER LIMIT
FL	Flat to gently undulating	0-3°	5.24
UD	Undulating	4-7°	12.3
RL	Rolling	8-15°	26.8
SR	Strongly rolling	16-20°	36.4
MS	Moderately steep	21-25°	46.6
ST	Steep	26-35°	70.0
VS	Very Steep	> 35°	>70.1

1.2 Geomorphic position

1.2.1 Landscape & landform

Landscape refers to the geomorphic location in the landscape. It can be determined from the surrounding landscape and the nature and/or origin of parent material. A 'landscape' is a broad assemblage or unique group of natural, spatially associated features, e.g. alluvial plain, mountain country, upland, volcanic field. A 'landform' is a discrete, natural, individual Earth-surface feature mappable at common survey scales, e.g. backswamp, bog, dune, fan, flood plain, hill, lahar, lava flow, mountain slope, pyroclastic flow deposit, slump, swale, tombolo, volcanic cone (Schoenberger et al., 2012). A collection of landforms makes up a landscape.

Landform refers to the geological feature within the selected landscape.
e.g. A valley (= landform) within mountain country (= landscape)

Landforms can be divided into components (e.g. backplain) and/or subdivided into elements (e.g. hollow). The term microtopography (or microfeature) refers to a discrete, natural earth-surface feature typically too small to delineate at common survey scales, e.g. bar, channel, lava flow unit, gully, mound, patterned ground features, terracettes.

Using Table 3, determine the landscape and landform. Slope stakes indicate the area over which slope/terrain position needs to be determined. Record the code on the scoresheet.

Full definitions can be found on pages 15 to 22 of Milne et al. (1995).

Table 3. Landscape and landform codes

1.2.1 Code for LANDSCAPE		**1.2.2 Code for LANDFORM**	
UP	Upland	**MT**	Mountain
MC	Mountain country	**VC**	Volcano
HC	Hill country	**HI**	Hill
HL	Hilly Land	**PT**	Plateau
LL	Low land	**MR**	Moraine
PL	Plain	**GO**	Gorge
		RV	Ravine
		VL	Valley
		DT	Delta
		FP	Flood Plain
		FB	Flood plain bench
		OP	Outwash Plain
		SP	Sand Plain
		TR	Terrace
		FA	Fan
		DU	Dune
		BG	Bog
		SW	Swamp
		CD	Caldera

1.2.2 Landform component & Element

Using Slope stakes indicate the area over which slope/terrain position needs to be determined.

Table 4*, choose the landform component, AND/OR a landform element, that best describes the environment that the pit/cutting is located in. Record the corresponding code, or codes, onto the scoresheet.*

Full definitions can be found on pages 15 to 22 of Milne et al. (1995).

Figure 1 illustrates a range of options within a hillslope environment to help visualise these features.

Not all codes for geomorphic positions are listed in this handbook; refer to Milne et al. for the full list and definitions.

Slope stakes indicate the area over which slope/terrain position needs to be determined.

Table 4. Landform component codes (adapted from Milne et al., 1995)

CODE for LANDFORM COMPONENT		CODE for LANDFORM ELEMENT	
AP	Apex	**Landform elements for relatively flat areas**	
CR	Crest	**MO**	Mound (higher part)
PT	Plateau	**HO**	Hollow (“closed” lower part)
CD	Caldera	**CN**	Channel (“open” lower part)
SU	Spur		
HE	Head	**Landform elements for hilly/mountainous areas**	
CL	Cliff	**SU**	Summit
SC	Scarp	**IF**	Interfluve area
TA	Talus slope	**RA**	Ridge area
DS	Dip slope	**AP**	Apex
LM	Lahar mound	**FL**	Flank
LO	Lobe	**SS**	Shoulder slope
TR	Tread	**US**	Upper slope
RS	Riser	**HS**	Head slope
BA	Bar	**NS**	Nose slope
GU	Gully	**MS**	Mid slope
LV	Levee	**FS**	Foot slope
DP	Depression	**TO**	Toe
BP	Backplain	**HO**	Hollow
ID	Interdune		

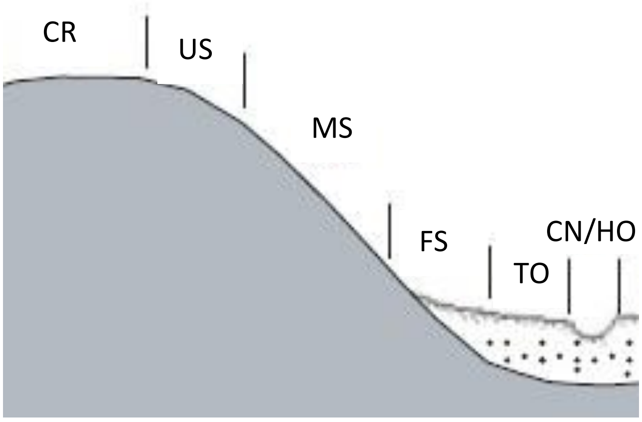

Figure 1. Slope positions (adapted from Schoeneberger et al., 2012)

1.3 Parent material (mode of origin & emplacement)

Use Table 5 *to determine the applicable parent material(s)* ***and*** *their mode(s) of emplacement. Record of the scoresheet.*

Up to two codes can be used for each category, e.g., aeolian sediment (loess), deposited over top of igneous colluvium (AO,SD & CL,IG).

If there are multiple layers of parent material from the same origin type and transport process, then the codes only need to be recorded once. If more than two parent material or modes of emplacement exist, then the two sets of processes in the uppermost horizons are recorded.

Appendix 1 provides additional information on volcanic landscapes and tephras to supplement Table 5.

Table 5. Types of parent materials & modes of emplacements (after Milne et al., 1995)

CODE	TYPE	DESCRIPTION
AO	Aeolian*	Wind transported sediments - e.g. loess, dune sand, dust.
BG	Biogenic*	Organic rock[§] produced by the remnants of living organisms both plant or animal e.g. limestone, peat.
CL	Colluvial	Unconsolidated, unsorted earth materials detached from slopes and transported under influence of gravity, assisted by water, and deposited on lower slopes (e.g. footslope).
FL	Fluvial	Sediment deposited by or related to water movement of rivers and stream; may occur on terraces above contemporary rivers/streams, or on floodplains, deltas, or fans.
GL	Glacial	Material or features relating to glacial activity. Also includes glacial lakes & ice caps or sheets.
IG	Igneous[¶]	Rock[§] or geological material solidified from molten or semi-molten material. Also includes any rocks affected by the formation of the above rocks (e.g. contact metamorphism).
LC	Lacustrine	Clastic sediments and chemical precipitates deposited in lakes.
LH	Laharic	Pertaining to or produced by a lahar.
MR	Marine	Rock[§] or material pertaining to, produced by, or formed in the sea or estuaries. Can be identified by presence of marine microfossils.
MM	Metamorphic	Rock or geological material pertaining to processes of metamorphism. Greywacke sandstone is classified in this event as a sedimentary rock. *[Metamorphism: rocks altered from their original condition by combinations of heat and/or pressure, causing a change in physical and chemical condition of the rock].*
OR	Organic Material	Any organic material (non-mineral) that doesn't fit into the biogenic or marine categories. Pertains to organic soils that have no mineral materials in the profile.
SP	Saprolitic	Pertaining to saprolite. *[Saprolite: a soft clay enriched material formed by weathering of rocks in place].*
SD	Sedimentary	Rock[§] or geological deposits pertaining to or containing sediment(s) that has been lithified, cemented, or compacted to some degree at some point in its history.

* Descriptions are simplified from Milne et al, pages 94-95. Refer to Milne for full descriptions.

[¶] See Appendix 1 outlining terms used for layered tephra parent materials in volcanic terrains.

[§] The term 'rock' implies hard, solid material that forms part of the surface of the Earth, and hence unconsolidated or weakly consolidated deposits, such as alluvium, colluvium, landslide debris, tephra, loess, peat, till, etc are not 'rock' by definition (Laffan and Mew, 1988). Instead, such unconsolidated deposits are often called cover beds or surficial deposits. Sometimes the term 'regolith' (Greek for 'blanket rock') is used as a general term for unconsolidated deposits of fragmental and earth material overlying bedrock and forming land surfaces. Note, however, that (consolidated) rocks can be described as 'hard' and 'soft' in New Zealand, the 'soft' rocks, such as the mudstones of the east coast and Rangitikei regions being less indurated (not as hard) and more readily broken down or eroded than so-called 'hard' rocks (e.g. see Hewitt et al., 2021).

1.4 Erosion/Deposition

Determine whether the site is currently, or very recently (within the last 10 years, with visible evidence of the process), erosional AND/OR depositional in nature.

Complete the relevant categories on the scoresheet using the codes in Table 6. Record ***X*** *in any non-applicable boxes to indicate you have determined that it is non-applicable.*

An off-limit area will be marked at EACH soil pit for evaluating erosion. **It is up to the competitors to determine whether erosion is applicable or not.**

Some locations may have more than one erosional and/or depositional process occurring; if this is the case then **only the dominant** erosional and/or depositional process is recorded.

Table 6. Classification of category of erosion & deposition (Milne et al., 1995)

CODE	NAME	DESCRIPTION
CH	Channel	Erosion and/or deposition by water flowing in stream and river channels, including stream bank erosion, and associated deposition.
CR	Creep	The slow, gradual, more or less continuous, non-reversible deformation sustained by soil and rock/geological material under gravitational stresses.
FA	Fall	A very rapid downward movement of a mass of rock/geological material or earth that travels mostly through the air by free fall, leaping, bounding, or rolling, e.g. rock fall, debris fall.
GU	Gully	Erosion creating gullies (steep erosion channel between 0.5–10 m deep), usually formed by water action.
RI	Rill	Erosion creating rills (steep erosion channel < 0.5 m deep), usually formed by water action.
RS	Rotational slip & slump	A slip or slump in which shearing takes place on a well-defined, curved shear surface, concave upwards in cross-section, producing backwards rotation in the displaced mass.
SC	Scree	Erosion which leads to production and deposition of scree downslope from the eroded area. (scree: loose broken rock fragments, created from erosion on steep landforms).
SH	Sheet	Erosion in which thin layers of surface material are gradually removed more or less evenly from an extensive area of sloping land.
TS	Translational slide	Downslope displacement of soil-rock material on a surface which is roughly parallel to the general ground surface. Includes landslide like events including debris slide, mud flows, liquefaction slides, loess flow etc.
TN	Tunnel (piping)	Erosion by percolating water in a layer of subsoil resulting in caving and the formation of belowground tunnels or pipes.
WI	Wind	Detachment, transport, and deposition of loose material by wind action.

1.5 Vegetation cover

Using the classes in Table 7, determine the dominant vegetation cover in the area surrounding, or immediately adjacent to, the pit. Record on the scoresheet.

The marked area indicated for section 1.4 Erosion/Deposition may also be used as a guide.

The dominant vegetation cover is determined by percentage cover of the landform. If two or more growth forms have similar cover percentage, then preference is given to the tallest class, e.g. in a mixed canopy forest/scrub the dominant vegetation class would be canopy forest.

A full list of possible classes and descriptions can be found on pages 28–31 of Milne et al. (1995).

Table 7. Vegetation cover codes (Milne et al., 1995).

CODE for VEGETATION CLASSES			
F	Forest	**SE**	Sedgeland
S	Scrub	**RL**	Rushland
T	Treeland	**RD**	Reedland
SL	Shrubland	**CF**	Cushionfield
TF	Treefernland	**HF**	Herbfield
VL	Vineland	**MF/LF**	Moss/Lichen-field
TL	Tussockland	**R**	Rockland
FL	Fernland	**BF/SF/GF/SD** **Z/C/L/P**	Boulder/Stone/Gravel/Sand-field Silt/Clay/Loam/Peat-field
GL	Grassland		

2. Soil Description

Refer to the section 'Soil Data' in Milne et al. (1995) for full information on soil description.

For the purposes of this event, the following soil data must be assessed:

2.1	Horizon designations
2.2	Horizon boundaries
2.3	Particle size
2.4	Structure and consistence
2.5	Soil matrix colour(s)
2.6	Redoximorphic features
2.7	Coatings

PROFILE DESCRIPTION GUIDE:

- A marker (nail) will be placed within the **third** horizon from the surface in the no-pick zone, with its depth recorded in the pit information.
- At each pit there will be a sign to indicate how many horizons, and to what depth, the soil must be described.
- There is no minimum horizon depth, except for transitional horizons (e.g. AB or A/B). For the purpose of this event, transitional horizons (i.e., boundaries between master horizons, e.g. A to B or B to C) should only be described if their thickness is greater than 8 cm and they have the appropriate properties (note that, outside this event, transitional horizons may also be less than 8 cm thick).

2.1 Horizon designations

For complete information on horizon notation, see Appendix 11 in Milne et al. (1995) (based on Clayden and Hewitt, 1989).

Horizon designations on the scoresheet are divided into four sections and are arranged sequentially from left to right as follows:

1. **Master prefixes:** Indicate properties such as buried horizons and differentiate parent materials through lithological discontinuities (definitions provided below).
2. **Master letters:** Indicate the type of horizon present (topsoil, upper and lower subsoil, etc.), as per Table 8. Master letter(s) must be notated as **capital** letters.
   Only one master letter is used per horizon, except for transition horizons, or unless specified as an option in Milne (e.g. CR horizon).
3. **Horizon suffixes:** Indicate the properties of the master horizon (which becomes a subhorizon), as per
4. Table 9 & Table 10. Suffixes must be notated as **lowercase** letters.
5. **Numeric suffixes:** Denote sequential horizons that share the same master and suffix code.

*All boxes for horizon designations **that do not require a code** must be filled with a dash.*

Master horizon prefixes

Numerical and letter prefixes are used to identify changes in parent materials (lithologies) and burial events.

Choose the correct combination and order of the prefixes and record on the scoresheet in the appropriate box. Null entries must be recorded with a dash.

Lithological discontinuities

A lithological discontinuity occurs when there is a change between two different parent materials due to a geological (not pedological) event or process. Such an event results in the deposition of new material of a certain lithology, such as a tephra layer or an alluvial or colluvial deposit. The incremental deposition of loess (aeolian sediment) is another example of a geological process.

The resulting profiles become multi-layered or multi-storied (sometimes called composite or compound profiles), representing upbuilding pedogenesis, as described in Appendix 1. These multi-layered/storied profiles, within the realm of soil stratigraphy, or pedostratigraphy, display vertical changes in features like particle-size distribution or mineralogical assemblages. These changes are attributable to geological events or processes, not pedogenic processes such as clay translocation.

Thus, lithological discontinuities represent geological changes or breaks (stratigraphic contacts) in the profile. They provide valuable stratigraphic information and should therefore be recorded. Once identified (correlated), tephras can also provide chronological information (via tephrochronology) if they have been dated (Table 36; Palmer et al., 2025).

Protocol for numbering lithological layers in soil profiles:

- Where a soil has formed entirely in one kind of material, no prefix number is needed (the entire profile is formed in a single lithology/geological material).
- In a multi-layered profile, the uppermost material is understood, by convention, to be lithology/material number 1, but the '1' is omitted.
- Numbering starts with the second layer of geological material (working downwards from land surface), which is designated 2. Underlying geological layers are numbered consecutively downwards in the sequence.
- All horizons formed in the same geological material (lithology) are prefixed with the same number.

Examples are given below, in
Figure 2, and Figure 18 (Appendix 1).

Buried horizons

Buried horizons, also known as paleosols (soils or soil horizons that have formed on a landscape or environment of the past; Palmer et al., 2005), are formed by the deposition of new geological material on top of an existing soil profile/horizon. This new material may have either a similar or dissimilar lithology to that of the buried material.

Buried soil horizons, even when only very weakly weathered, mark soil formation that took place through topdown processes when that parent material (e.g. tephra) was at the land surface. They represent disconformities and carry information on landscape evolution, climate, and time. The boundary between the top of a buried soil and an overlying tephra or other geological deposit is a paraconformity, marking a period of non-deposition (Hopkins et al., 2021).

Protocol for designating buried horizons in soil profiles:

- Buried horizon(s) are denoted with a lower case b, listed before the master horizon designation (e.g. bAh). All horizons formed in the geological material arising from the same burial event/deposit are denoted with the same prefix.

Examples are given below, in
Figure 2, and Figure 18 (Appendix 1).

Numeric suffix

When a horizon (e.g., Bt) needs to be subdivided due to sequential horizons with the same master horizon and suffix, numerical suffixes are added to the end of the horizon notation to distinguish between them. Numbering restarts if the master horizon and suffix designation changes, except in cases of lithological discontinuities (burial events will restart numbering).

If applicable, record the numeric suffix in the appropriate box on the scoresheet. Null entries must be recorded with a dash.

Example 1:

Bt1
Bt2
Btg1
Btg2
(*not* Bt1, Bt2, Btg3, Btg4)

Example 2:

Bw1
Bw2
…lithological discontinuity…
2bBw1
2bBw2

Example 3:

Ap
…lithological discontinuity…
2bBw1
2bBw2
…lithological discontinuity…
3bBw1
3bBw2
3Cu

Note on the ‘b’ prefix for buried horizons

The prefix ‘b’ denotes a soil horizon with features formed by pedogenesis before its burial (i.e., when it was at or near the land surface). Buried C horizons do not carry ‘b’ prefixes as they lack soil features, i.e. they are geological layers. However, BC horizons, which show slight pedological transformation, do receive a ‘b’ prefix (e.g., see

Figure 2). Note that in *Soil Taxonomy (Soil Survey Staff, 2022)*, the ‘b’ is added as a suffix rather than prefix.

Example: Lithological discontinuities, buried soils/soil horizons, and numeric suffixes combined (soil formed by retardant upbuilding pedogenesis: 5 ‘mini’ soil profiles atop one another)

Ah	Ah horizon, formed in lithology 1 (= geological material 1)
Bw1	Bw horizon, formed in lithology 1 (= geological material 1) *Suffix numeral 1 added because of another similar (second) Bw horizon below*
Bw2	Bw horizon, formed in lithology 1 (= geological material 1) *Suffix numeral 2 added due to already recording a Bw horizon above*
Bw(f)	Bw (with ≥2% redox segregations) formed in lithology 1 (= geological material 1) *No suffix numeral needed because this is a Bw(f) horizon (i.e. not a plain Bw)*
…………………	*1st lithological discontinuity = marks burial by geological deposit (e.g. tephra layer, alluvium, colluvium) as a consequence of a geological event/process such as a volcanic eruption or river flooding or landsliding*
2bAh	Ah of a buried soil, formed in lithology 2 (= geological material 2*) *2 marks lithology 2, 2bAh is upper horizon of buried soil in this lithology/material*
2bBw	Bw of a buried soil, formed in lithology 2 (= geological material 2) *2 marks lithology 2, 2bBw is lower horizon of buried soil in this lithology/material*
…………………	*2nd lithological discontinuity (= burial by geological deposit)*
3bAh	Ah of a buried soil, formed in lithology 3 (= geological material 3) *3 marks lithology 3, 3bAh marks upper (and only) horizon of buried soil in this lithology/material*
…………………	*3rd lithological discontinuity (= burial by a geological deposit)*
4bBw	Bw of a buried soil, formed in lithology 4 (= geological material 4) *4 marks lithology 4, 4bBw marks upper horizon of buried soil in this lithology/material*
4Cu	Cu of a buried soil, formed in lithology 4 (= geological material 4) *4 marks lithology 4, 4Cu represents lithology/parent material of this buried soil*
…………………	*4th lithological discontinuity (= burial by a geological deposit)*
5bAh	Ah formed in lithology 5 (= geological material 5) *5 marks lithology 5, 5bAh marks upper (and only) horizon of buried soil in this lithology/material*

* Irrespective of lithology type (i.e. lithology 2 may be similar to, or different from, lithology 1). The key is to record each geological deposit in the profile using the numeral prefixes that denote deposits from each geological event, regardless of compositional similarity or difference over time. These breaks, technically termed geological or stratigraphic ‘contacts’, are geological (not pedological) in origin and should be recorded simply and systematically down the sequence.

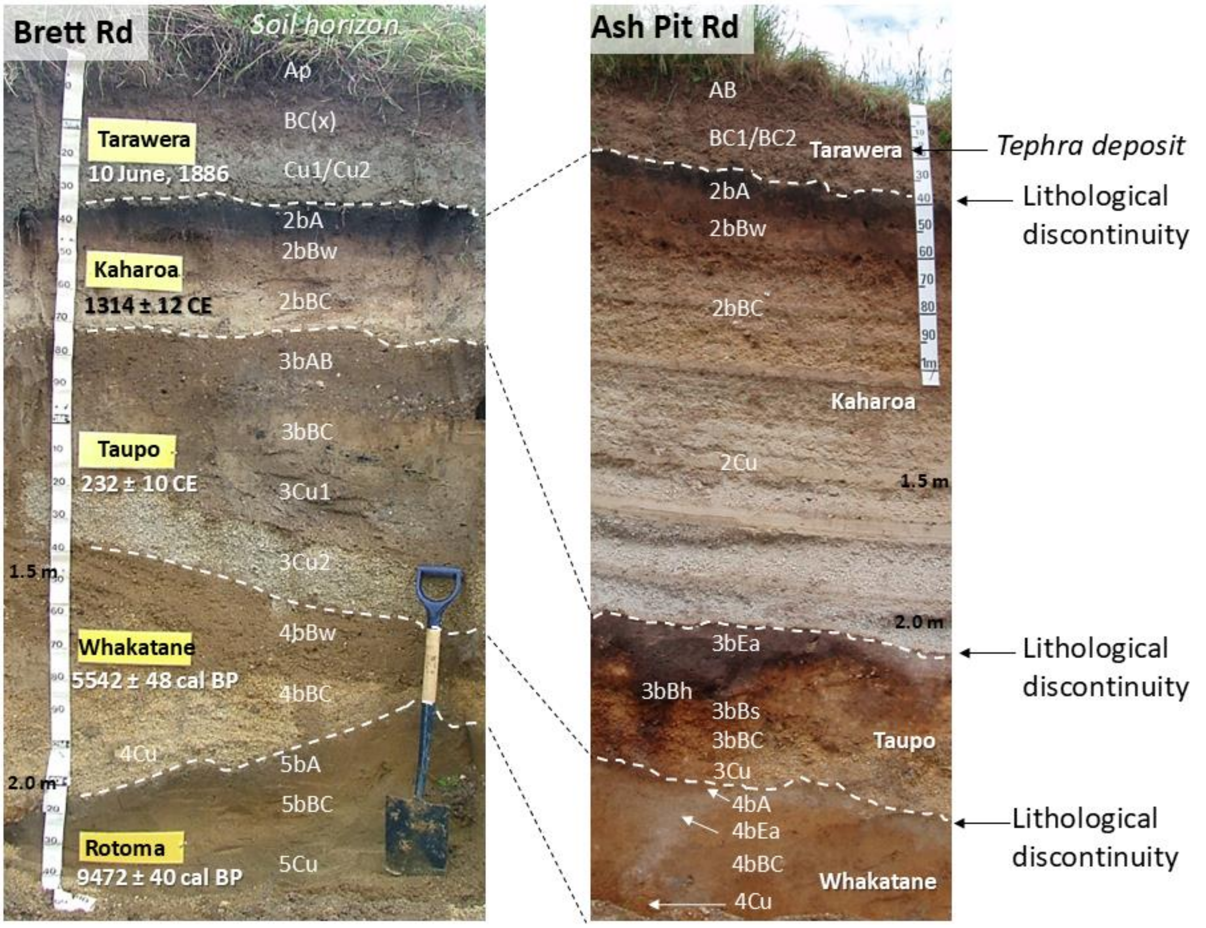

Figure 2. Multi-layered, tephra-derived, soils formed through retardant upbuilding pedogenesis near Mt Tarawera, illustrating lithological discontinuities and buried soil horizons and associated horizination (modified after Clayden and Hewitt, 1989). The names and dates/ages refer to separate tephra-fall events during the Holocene (see Appendix 1 and supplementary notes). The discontinuities mark geological (not pedogenic) contacts hence a new numeral prefix is added. The buried soil horizons are indicated using the prefix 'b', denoting a soil horizon with features formed by pedogenesis (at the land surface) before burial. The Cu horizons do not have 'b' prefixes because they have no soil features, i.e. they are geological layers. The soil on the left is a Typic Udivitrand, and on the right a Vitrandic Udorthent (Soil Survey Staff, 2022) in which buried spodic (podzolic-B in NZSC) and albic (pale eluviated E horizon in NZSC) materials are evident below 2 m. Photos by R. McEwan and H.S. Jones. Image modified after Hartemink et al. (2020).

Master horizon notation

Select the appropriate master horizon notation(s) (which always have capital letters) as per Table 8 and record in the appropriate box on the scoresheet.

Table 8. Master letter horizon designations options

MASTER HORIZONS	
O	Organic material, accumulated under wet conditions such as on peat*.
A	Mineral horizon formed at the soil surface characterised by incorporation of humified organic matter.
E	Horizon below the O, or A horizon that has lost clay, iron or aluminum (eluviated) leaving it relatively pale.
B	Mineral horizon that has been altered by formation of soil structure, brighter colours (than horizon above and below), or by enrichment in mineral or organic material.
C	Underlying unconsolidated material, potentially showing some weathering, but minimal biological activity.
R	Underlying bedrock (if present) (hard or very hard bedrock that is impracticable to dig with a spade).
TRANSITIONAL MASTER HORIZONS	
A/B	Combinations of recognizable discrete parts of two master horizons *(A and B are an example only).*
AB	Transitional between any two master horizons *(A and B are an example only).*

* Organic material accumulated under drier conditions, such as beneath native forest, and containing at least 18% organic carbon (30% organic matter) is designated as follows: L (fresh litter), F (partly decomposed or comminuted litter), or H (well decomposed litter, no visible plant structures) (Clayden and Hewitt, 1989).

Transitional master horizons

There are two kinds of transitional horizons: (1) those with two recognisably discrete parts (separate), and (2) those with properties of two horizons that gradually merge, e.g. an AB horizon is between an A and B horizon in character.

1. **Separate parts**: Horizons in which distinct recognisable properties of two kinds of master horizons are indicated, with the two capital letters separated by a slash (/) – for example, A/C, E/B, B/C. Typically, most individual parts of one component are surrounded by the other. Suffixes may be applied to each master horizon, as per
2. Table 9. Suffixes should be listed in the letter suffix column in the same order as the master horizons, separated by a slash, e.g., A/B, p/w(g)*
   *This method of writing subhorizon suffixes, e.g., p/w(g), is specific to soil judging and differs from Milne et al. (1995).

3. **Properties of two**: For horizons with properties that transition between two master horizons, two capital letter symbols are combined, such as AB, EB, BE, and BC. The master horizon symbols are used in the order A, E, B, C, regardless of which properties are more dominant. Select the suffix(es) that best represent the properties of the entire horizon, following Table 9, and record them in the letter suffix column.

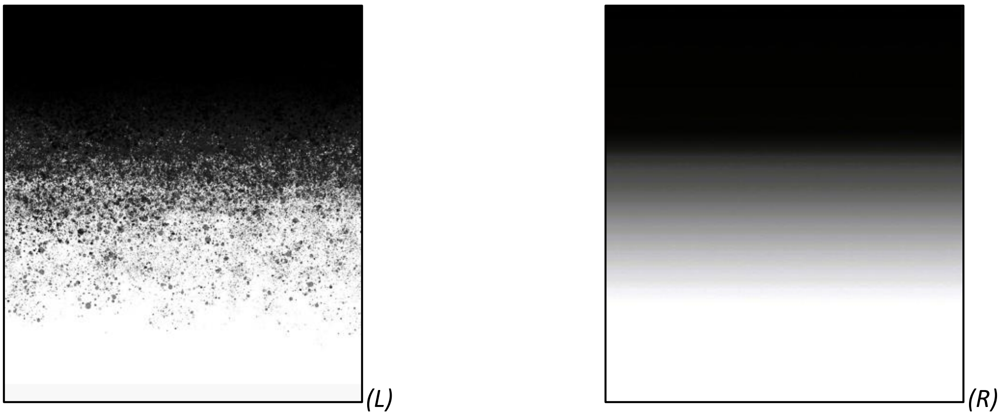

Figure 3. Example of transition horizons. Left - A/B horizon (separate parts); right - AB horizon (properties of the two).

Subhorizon suffix notation

Select the appropriate suffix(es) to form subhorizons as per Table 9 *&* Table 10 *and record in the appropriate box on the scoresheet. Null entries must be recorded with a dash.*

Table 9. Letter suffixes

In A horizons the following letter suffixes are acceptable (choose 1)

h	An A horizon in which there is no evident disturbance due to cultivation or pastoral land use.
p	An A horizon, in which incorporation of organic matter has involved mixing due to cultivation or to increased biological activity associated with topdressing or manuring. It may contain material from pre-existing E, B or C horizons.
hg/pg	A horizon meeting the conditions for an p or h horizon, but also contains > 2 % redox segregations (usually found along root channels)

For B horizons the following letter suffixes are acceptable (at least 1, maximum of 2).

fm	Sharply defined, cemented, pan-like B horizon usually less than 10 mm thick but the same designation is given to horizons up to 25 mm thick. It is black to reddish brown or dark red in colour, and a black upper part can often be distinguished from a reddish-brown lower part. It lies roughly parallel to the soil surface but is commonly wavy or convolute. A Bfm horizon usually occurs as a single pan but in places it can be bifurcated. It forms a barrier to most roots and restricts water movement.
g	A strongly gleyed B horizon with more than 2% redox segregations and in which greyish colours, as specified below, occupy 50-85% of the matrix exposed in a cut face of the horizon or are dominant on ped faces.
h	Dark-coloured B horizon of podzolised soils enriched in organic matter, associated with aluminium, or iron and aluminium, as a result of illuviation.
k	To denote an accumulation of secondary carbonate.
o / o(f) / o(g) / og / or	A strongly weathered B horizon formed in mixed crystalline iron and aluminium oxides and kaolin minerals, with low activity clay properties. Refer to Table 11 for redox options.
r	Intensely gleyed B horizon with predominantly greyish (low chroma) colours and usually few redox segregations.
s / s(f) / s(g)	Ochreous B horizon of podzolised soils containing illuvial aluminium, iron, or both, that is closely associated, or complexed, with illuvial organic matter. The aluminium and iron are apparently mainly present as nanocrystalline minerals (with short-range-order) (especially allophane and ferrihydrite), though some aluminium is often present as aluminium-humus. Refer to Table 11 for redox options.
t / t(f) / t(g) / tg / tr	B horizon containing translocated clay. It is required to have less than 2% redox segregations. Refer to Table 11 for redox options.
w / w(f) / w(g)	B horizon that shows evidence of alteration under well aerated conditions and does not qualify as Bh, Bs or Bt. Refer to Table 11 for redox options.
x / x(g) / xg	Denote a horizon with fragipan properties. Refer to Table 11 for redox options.

Table 9 continued.

For C horizons the following letter suffixes are acceptable (at least 1, maximum of 2).

g	A strongly gleyed C horizon with more than 2% redox segregations in which greyish colours as specified below occupy 50–85% of the matrix exposed in a cut face.
r	Intensely gleyed C horizon with greyish colours with chromas of 2 or less occupying more than 85% of the matrix exposed in a cut face.
x	To denote a horizon with fragipan properties.

For E horizons the following letter suffixes are acceptable (at least 0, maximum of 1).

a	An E horizon in which weathered films on sand and silt particles are absent, very thin or discontinuous, so that the colour of the horizon is mainly determined by the colours of uncoated grains and redox segregations are absent. Not saturated with water and usually overlying Bh or Bs.
g	An E horizon with greyish colours and redox segregations with dominant moist chroma of 2 or less, or moist chroma of 3 with values of 6 or more, and with more than 2% redox segregations. Normally overlies Bg or Btg but can overly Bfm or Bh.
r	An E horizon with dominantly grey colours attributable to reduction and removal of iron due to prolonged waterlogging. It has dominant moist chroma of 2 or less, and 0% or <2% redox segregations. Usually underlies an O horizon and overlies a Bg, Btg, Br, Bfm or Bh.
w / w(g)	An E horizon with dominantly brownish colour, it has a moist chroma of 4 or more but less than 6, and with less than 2% redox segregation (Ew, or enough segregations to qualify as Eg (Ew(g)).

Table 10. Suffixes used to express degrees of gleying in B horizons (adapted from Milne et al., 1995)

	% Redox Segregations*	**% Low Chroma Colours***		
		In matrix		**On ped faces**
Bw, Bt, Bs, Bo	<2	none		none
Bw(f), Bt(f), Bs(f), Bo(f)	≥2	none	and	none
Bw(g), Bt(g), Bs(g), Bo(g), Bx(g)	≥2	<50	/	<50
Bg, Btg, Bog, Bxg	≥2	50-85	or	>50
Br, Btr, Bor	Not diagnostic	>85		Not diagnostic

* Abundance charts can be found in Appendix 2 of Milne et al., 1995, and also in Section 6, Figure 15 of this handbook.

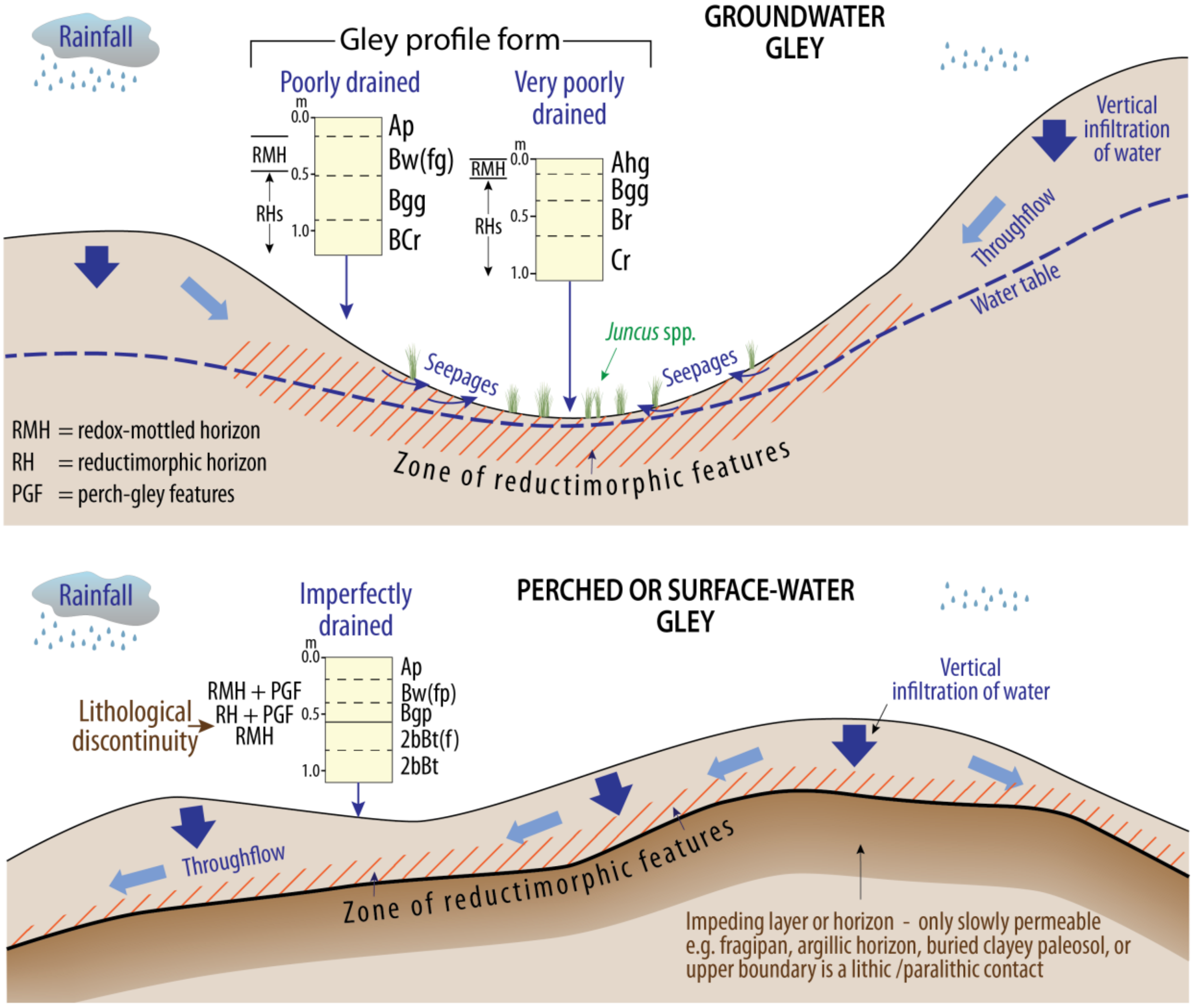

Figure 4. Examples of landscape positions with Gley Soils. The schematic soil profile insets show examples of typical soil horizonation, including associated drainage classes and diagnostic horizons (New Zealand Soil Classification). Top: groundwater-gley soils in a seepage zone at the foot of a hill. Bottom: perched-gley soils formed above a slowly permeable horizon. RMH = redox mottled horizon, RH = reductimorphic horizon, PGF = perch-gley features. From Hewitt et al. (2021).

2.2 Horizon boundaries

For complete information on horizon boundary descriptions see Milne et al. (1995, pp. 35–40).

2.2.1 Depth to lower boundary

Measure depth between the tapes in the “no-pick” zone on the pit wall. Depth measurements will be considered accurate within a range based on the distinctness and topography of the boundary.

For all horizons except the last, determine the depth in centimetres (to the nearest cm) from the top of the mineral soil surface to the lower boundary. Record on the scoresheet.

The last horizon boundary should be the specified judging depth. For example, if the pit sign states “Describe 5 horizons to a depth of 140 cm”, the fifth depth designation should be:

- “140” if the specified depth is at a lithic or paralithic contact, or,
- “140+” if the specified depths is not at a lithic or paralithic contact.

2.2.2 Boundary distinctness

Determine the distinctness of the horizon boundaries following

The boundary distinctness for the bottom horizon will be determined by the presence, or lack, of a horizon below the final described horizon. If the last horizon ends at the base of the soil pit/profile/regolith, then record a dash. If there is a horizon below and the boundary can be described, then record the appropriate codes for BOTH distinctness and shape.

Table 11. Classification of horizon boundary distinctness (Milne et al., 1995).

DISTINCTNESS

Code	Class	cm
SH	Sharp	<0.5
AB	Abrupt	0.5–2
DS	Distinct	2–5
ID	Indistinct	5–10
DF	Diffuse	≥10

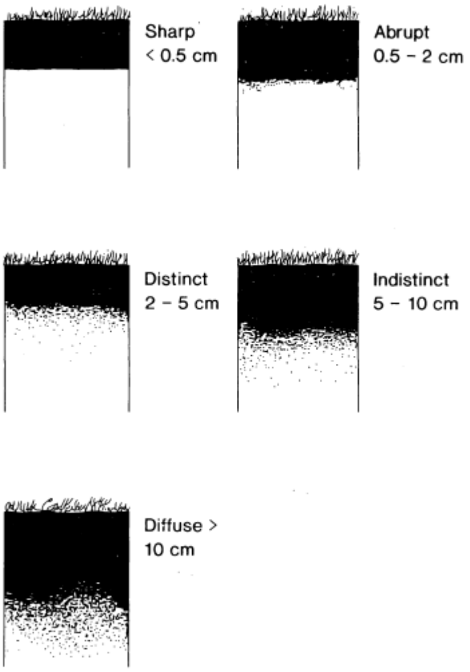

Figure 5. Visualization of horizon boundary distinctness classes (Milne et al., 1995).

2.2.3 Boundary topography

Determine the topography of the horizon boundaries following Table 12 and Figure 6. Record the corresponding codes on the scoresheet.

As per section 2.2.2 Boundary Distinctness, if the is a horizon below the last described horizon, then record the topography. If not, record a dash.

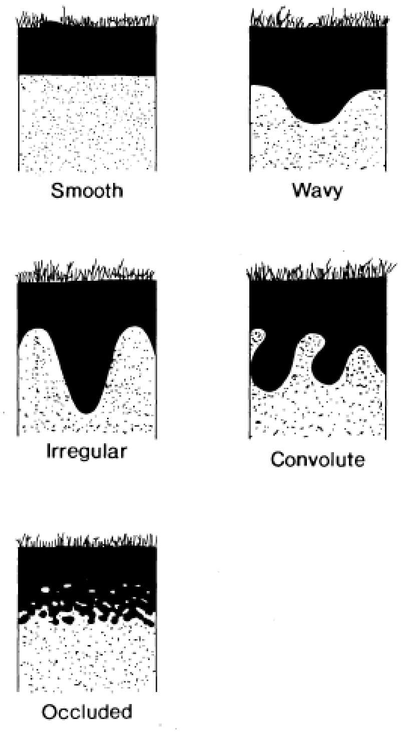

Table 12. Classification of horizon boundary topography (Milne et al., 1995).

TOPOGRAPHY

Code*	Class	Determination
S	Smooth	Nearly plane surface
W	Wavy	Pockets less deep than wide
I	Irregular	Pockets more deep than wide
C	Convolute	Discontinuous

* Any of the classes can be qualified by the term "occluded" if the boundary zone contains domains of upper and lower horizons. Occluded boundaries are given the topography codes SO, WO, IO, BO.

Figure 6. Visualisation of horizon boundary topography classes (Milne et al., 1995).

2.3 Particle Size

For complete information on particle size descriptions see Milne et al. (1995), pages 45 to 52. Especially note the particle-size fractions (i.e. boundaries of size fractions, page 45).

Determine the texture class for the fine-earth fraction (particles < 2mm). First use the texture determination flow chart (Figure 7) for an initial texture class determination. Then use the texture triangle (Figure 8) to fine tune texture class.

Use Figure 8. *Soil texture triangle (Milne et al., 1995).*

Use Table 13 *to find the code coinciding to the texture class and record this into the scoresheet.*

Definitions

- **Bolus**: handful of moistened soil able to retain its shape after moulding.
- **Polish**: smooth shiny surfaces to soil (bolus) when rubbed with a fingernail.

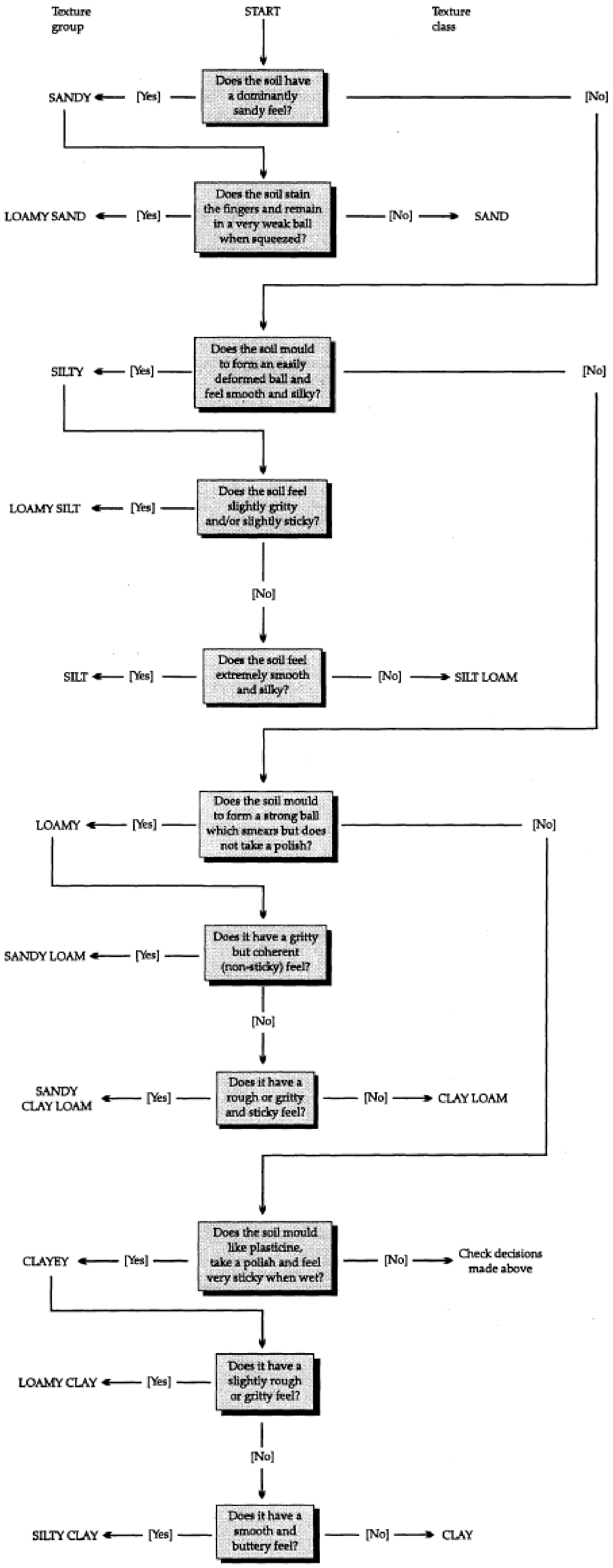

Figure 7. Texture determination flowchart (Milne et al., 1995).

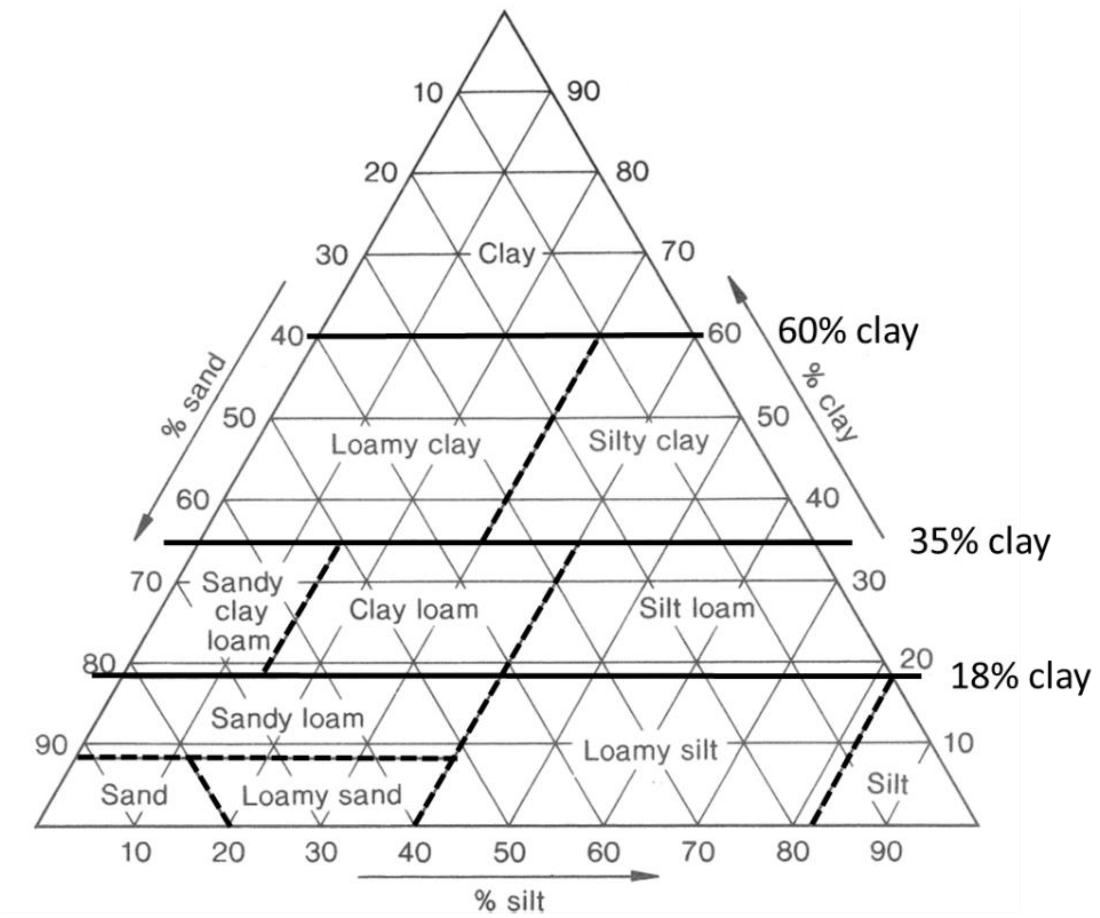

Figure 8. Soil texture triangle (Milne et al., 1995).

Table 13. Codes for texture classes (Milne et al., 1995).

CODE	TEXTURE	TEXTURAL CLASS DEFINITION
S	Sand	>80% sand and <8% clay
LS	Loamy sand	>80% sand, <40% silt, <8% clay
SL	Sandy loam	>8% clay and <40% silt
LZ	Loamy silt	40% - 82% silt
Z	Silt	>82% silt
SCL	Sandy clay loam	<15% silt
CL	Clay loam	15%–40% silt
ZL	Silt loam	>40% silt
LC	Loamy clay	<60% clay, <30% silt
ZC	Silty clay	<60% clay, >30% silt
C	Clay	>60% clay

Coarse fragments

Depending on the abundance and size of the rock fragments, modifiers to the texture class may be required.

Estimate the percentage volume of soil particles coarser than sand (>2 mm) using the abundance charts in Section 6 (**Figure** 15) of this handbook or in Appendix 2 of Milne et al. (1995).

- **35%** by volume of gravel approximately represents the boundary between materials in which the gravels seem to be entirely 'floating' in the fine-earth matrix, and materials in which pieces of gravel are to some extent touching one another.
- **70%** by volume of gravel broadly represents the boundary beyond which individual pieces of gravel are in complete contact, and any fine-earth is confined to interstices (Milne et al., 1995).

Use Table 14 to find the corresponding abundance class code and record this on the scoresheet.

Table 14. Gravel and boulder abundance by volume (Milne et al., 1995).

CODE	ROCK FRAGMENT VOLUME %	TEXTURE MODIFIER CLASS
1	<1	Non-gravelly (stoneless*)
2	1-5	Very slightly gravelly
3	5-15	Slightly gravelly
4	15-35	Moderately gravelly
5	35-70	Very gravelly
6	>70	Extremely gravelly

* If stoneless (i.e., Between 0% and <1% coarse fragments), use **X** for size class.

The dominant rock fragment size is the size category that makes up the largest volume of all rock fragments within the horizon.

Determine the dominant rock fragment size class using Table 15 and record it on the scoresheet.

Table 15. Gravel and boulder size classes (Milne et al., 1995).

CODE	ROCK FRAGMENT SIZE MM	ROCK FRAGMENT SIZE CLASS
X	Non applicable (for stoneless horizons)	
FG	2-6	Fine gravel
MG	6-20	Medium gravel
CG	20-60	Coarse gravel
VCG	60-200	Very coarse gravel
B	>200	Boulders

2.4 Structure & Consistence

Soil structure is the component of the macrofabric that encompasses soil aggregates and the voids between them (Hodgson, 1976, in Milne et al., 1995). It refers to the shape, size and degree of development of aggregation of the primary soil particles into structural units. The term *soil aggregate* refers to any distinct lump or cluster of primary soil particles, and includes peds, casts, clods and fragments.

Degree of pedality

Determine if aggregates are present. If the soil contains less than 15% aggregates, classify it as X (structureless). If it contains more than 15% aggregates, refer to Figure 9 to identify the type of aggregates and use Table 16 to assess the degree of pedality. Record the degree of pedality class code on the scoresheet.

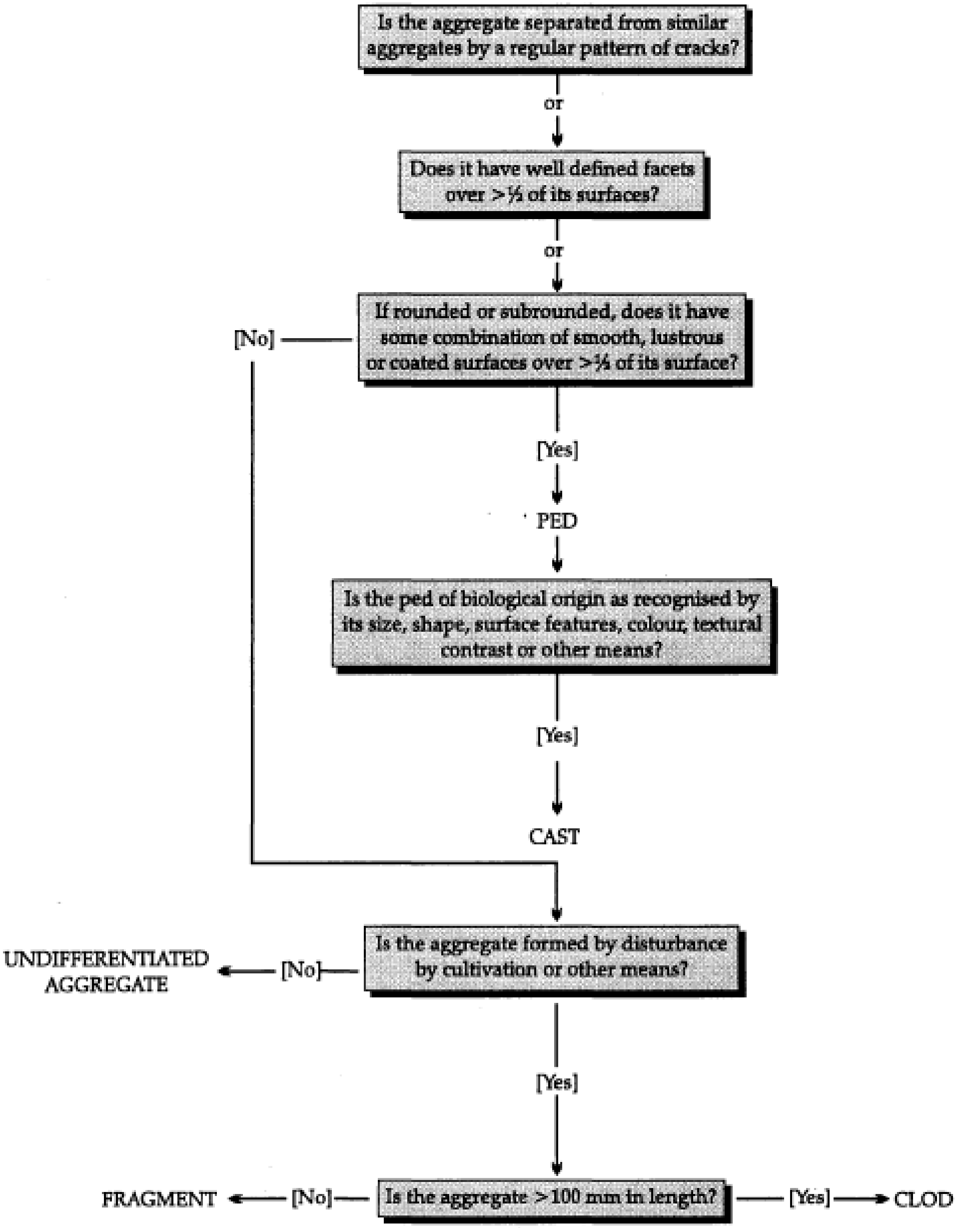

Figure 9. Flowchart for aggregate identification (Milne et al., 1995, p. 59).

Table 16. Degree of pedality for soil materials (Milne et al., 1995, p. 60).

CODE	CLASS	DEFINITION
X	Structureless	Apedal. Contains less than 15% in peds*.
W	Weak	Peds are barely observable in place, 15-25% in peds.
M	Moderate	Peds well-formed and evident in place, 25-75% in peds.
S	Strong	Peds are distinct in place, >75% in peds.

* Percentage by weight of fine-earth soil material consisting of peds.

Apedal materials

If the degree of pedality was recorded as Structureless (i.e. X), use the flowcharts in Figure 10 and Table 17 to identify the type of structureless (apedal) material. Record the correct code on the scoresheet.

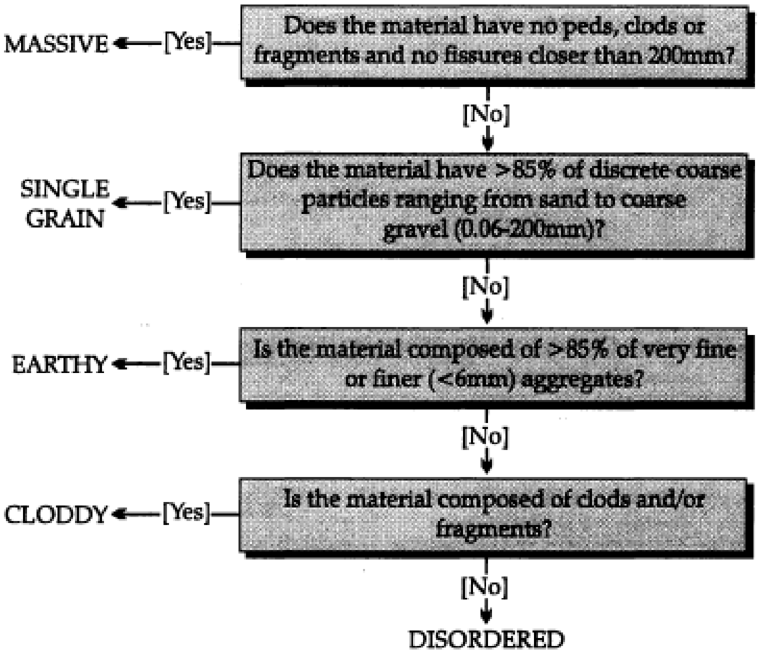

Figure 10. Flowchart for identification of apedal materials (Milne et al., 1995, p. 60).

Table 17. Type of structureless or apedal materials (Milne et al., 1995, p. 58).

CODE	TYPE	DEFINITION
MA	Massive	Material without peds, clods or fragments, and having no fissures at spacings of less than 200 mm.
SG	Single grain	Material with more than 85% by weight of discrete primary particles ranging in size from sand to very coarse gravel.
EA	Earthy	Material composed of more than 85% by weight of very fine or finer (< 6 mm) aggregates.
CL	Cloddy	Material formed in recently cultivated surface horizons and composed dominantly of clods and fragments.
DI	Disordered	Apedal material that does not meet the specifications of massive, single grain, earthy or cloddy.

Type of structure for pedal material

If the degree of pedality has been described as weak (W), moderate (M) or strong (S) use Figure 11, Figure 12, and Table 18 to identify the type or shape of the structural units. Record the correct code from Table 18 onto the scoresheet.

For the purposes of this event, only the most dominant structure type by percent volume occupied will be described for each horizon.

Shapes are identified using the following convention (see Figure 12):

- Measure the longest axis about which the shape will rotate symmetrically.
- Measure the shortest axis at right angles to the longest axis.
- Measure the intermediate axis at right angles to the other two axes.

Ratios between these axes $\left(\frac{intermediate}{longest}\ and\ \frac{shortest}{intermediate}\right)$ are used as quantitative indicators in Table 18.

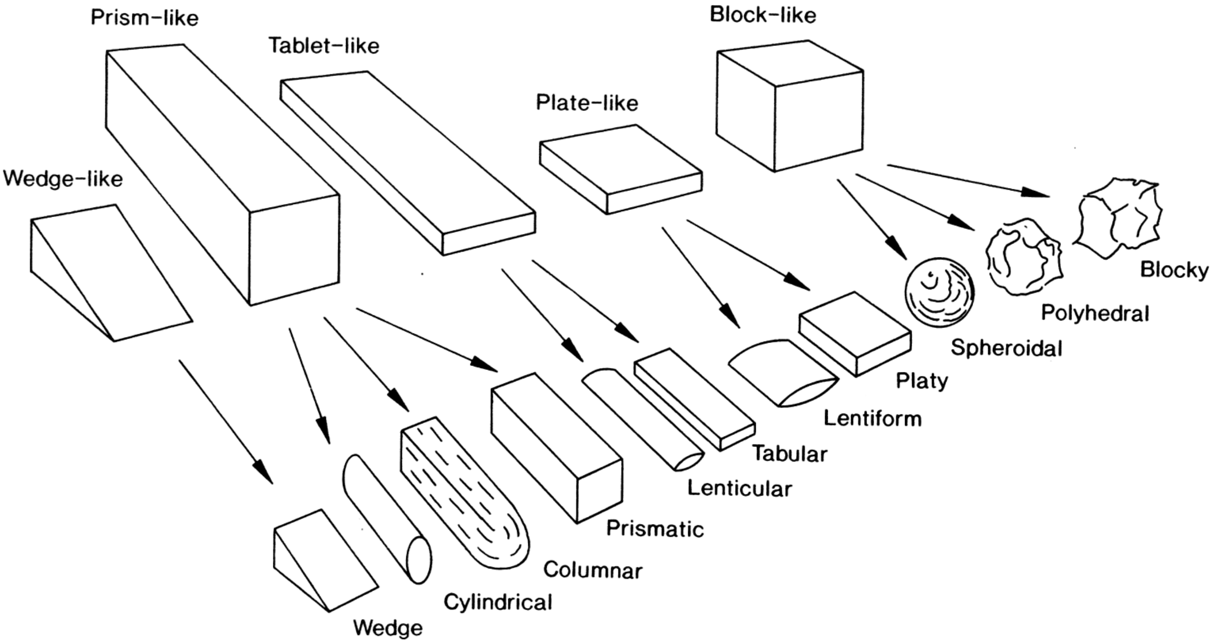

Figure 11. Simple structural shapes (Milne et al., 1995, p. 69)

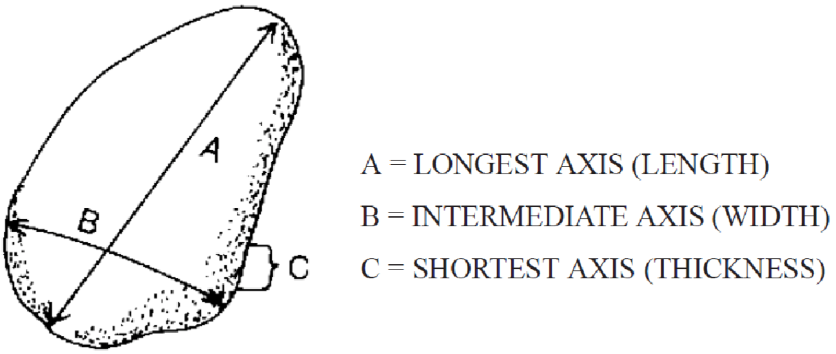

Figure 12. Image representing axes measurements (Harrelson, Rawlens and Potyondy, 1994).

Table 18. Classification of simple shapes of soil structure (from Milne et al., 1995, p. 68).

CODE	SHAPE CLASS	AXIAL RATIO		ROUNDNESS	OTHER NECESSARY PROPERTIES
		$\frac{intermediate}{longest}$	$\frac{shortest}{intermediate}$		
		BLOCK-LIKE			
BL	Blocky	> ½	> ½	angular-subrounded	majority of angles between faces <90°
PH	Polyhedral	> ½	> ½	angular-subrounded	majority of angles between faces >90°
SR	Spheroidal	> ½	> ½	rounded	
		TABLET-LIKE			
TB	Tabular	< ½	< ½	angular-subrounded	
LT	Lenticular	< ½	< ½	rounded in cross-section	
		PRISM-LIKE			
PM	Prismatic	< ½	> ½	angular-subrounded	flat ends
CO	Columnar	< ½	> ½	angular-subrounded cross-section	multifaceted or rounded ends
CL	Cylindrical	< ½	> ½	rounded cross-section	ovate or circular cross-section
		PLATE-LIKE			
PL	Platy	> ½	< ½	angular-subrounded	
LF	Lentiform	> ½	< ½	rounded	
		WEDGE-LIKE			
WL	Wedge	no restriction	< ½	no restriction	

Size of structural units

Determine the applicable size class(es) for structural units. Using Table 19, choose one or more appropriate classes for the dominant structure type (e.g., "size 3–5" or "sizes 1 & 4") and record on the scoresheet. If structureless use ***X*** *for size class.*

Table 19. Structural unit and root size classes (Milne et al., 1995).

CODE	SIZE CLASS	SIZE RANGE
1	Microfine	<1
2	Extremely fine	1-2
3	Very fine	2-6
4	Fine	6-10
5	Medium	10-20
6	Coarse	20-60
7	Very coarse	60-100

Consistence – Soil Strength or Resistance to Crushing

The strengths of minimally disturbed soil samples, at field water content, are determined as the resistance to crushing of an unconfined volume of soil (Milne et al., 1995). Ideally, a **30-mm cube sample of undisturbed soil** should be used for sampling.

In practice, standard cube samples will include aggregates or parts of aggregates, or they will be cut from larger aggregates, and some will be cut from apedal soil materials.

Apply pressure on horizontal faces of cube samples *(as oriented in the profile). Use Table 20 to determine cube strength, and Table 21 to record the failure mode. Record the correct codes on the scoresheet.*

If a test specimen cannot be obtained (due to conditions such as apedal material) record soil strength as **very weak**.

Table 20. Strength, or resistance-to-crushing, of field MOIST soil samples (Milne et al., 1995, p. 83).

CODE	CLASS	METHOD	CONDITIONS OF FAILURE OF 30 MM CUBE
1	Very weak	Force applied between extended forefinger and thumb.	Fails under very gentle force
2	Weak		Fails under gentle force
3	Slightly firm		Fails under moderate force
4	Firm		Fails under strong force, the maximum that most people can exert
5	Very firm	Force applied slowly under foot on a hard flat surface or between both hands locked.	Fails with gentle force under foot; can be crushed between locked hands of average person
6	Hard	Force applied slowly under foot on hard surface.	Fails under the force which is applied slowly by full body weight of ~80 kg.
7	Very hard		Withstands the force applied slowly under foot by average body weight of ~80 kg.

Consistence - Failure

Table 21. Failure classes for soil consistence (Milne et al., 1995, p. 84).

CLASS CODE		CLASS DEFINITION
V	Very friable	Test sample cannot be formed or crumbles under very slight stress on crushing within the hand, into aggregates predominantly < 2 mm in size. In most instances the test sample is difficult to obtain.
F	Friable	Test sample cannot be formed or crumbles under very slight stress, into aggregates predominantly > 2 mm in size, or under slight stress into aggregates predominantly < 2 mm in size
B	Brittle	Under slowly increasing pressure, the test sample retains its size and shape, with few to no cracks, until it abruptly fractures into aggregates of > 2 mm in size
S	Semi-deformable	Under slowly increasing pressure, the test sample is compressible in the direction of pressure. The sample will develop cracks and/or rupture before reaching half its original thickness.
D	Deformable	Under slowly increasing pressure, the test sample is compressible in the direction of pressure, to at least half its original thickness without cracks or rupture.

2.5 Soil matrix colour(s)

For routine descriptions, the moist colour(s) of the soil matrix should be determined out of direct sunlight, and by matching the surface of a broken ped (fresh not worked) with the colour chip of the Munsell Soil Colour Charts.

For each horizon described, use the Munsell Soil Colour Charts to determine the primary matrix colour, and where applicable the secondary matrix colour.

*Colours must be designated by **Hue**, **Value,** and **Chroma**. Record each of these on the scoresheet in the appropriate location.*

Redoximorphic features and coatings are described separately in sections 2.6 and 2.7, respectively.

2.6 Redoximorphic features

Redoximorphic features are colour patterns in a soil resulting from loss (depletion) or gain (concentration) of pigments relative to the matrix colour. These patterns occur due to the oxidation and reduction of iron (Fe) and/or manganese (Mn), along with their movement (removal, translocation or accrual). Fe or Mn reduction typically happens when free oxygen is limited or absent in a soil volume or horizon, often due to prolonged water saturation. Oxidized Fe generally appears redder or yellower than surrounding soil particles, while Mn often appears darker than adjacent particles.

Redox concentrations are localised zones of enhanced pigmentation resulting from the accumulation of Fe-Mn minerals. They may occur as:

- ***Nodules and concentrations***: Cemented bodies of Fe-Mn oxides; concentrations have internal rings, while nodules do not.
- ***Mottles***: Non-cemented bodies of enhanced pigmentation, displaying a redder or blacker colour than the surrounding matrix (referred to as “masses” in Schoeneberger et al., 2012). *Note:* Mottles are spots, blotches or streaks of subdominant colours differing from the matrix colour and from the ped surface colour. Colour patterns due to biological or mechanical mixing, or inclusions of weathered substrate material, are not considered to be mottles.

Redox depletions are defined as zones with chromas less than 2. They can be greyer, lighter or less red than the adjacent matrix. They may occur as:

- ***Iron depletions***: Areas with reduced amounts of Fe and Mn oxides but similar clay content to the surrounding matrix.
- ***Clay depletions***: Areas with reduced amounts of Fe, Mn, **and** clay compared to the surrounding matrix.

If the matrix is described as a depleted colour, with a value of ≤2, depletion should be indicated in the horizon designation, and NOT as a redoximorphic feature. Only redoximorphic concentrations should be in the redoximorphic feature column.

Determine the type of redoximorphic features according to Table 22. Record the correct class code on the scoresheet.

Table 22. Types of redoximorphic features.

CLASS CODE	CLASS DEFINITION
N	No redoximorphic features.
C	Hard nodules and concentrations.
D	Iron depletions with value ≥ 4 and chroma ≤ 2. Clay depletions.
C/D	Concentrations and depletions with value ≥ 4 and chroma ≤ 2.
M	Non-cemented concentrations of re-oxidised Fe and/or Mn.

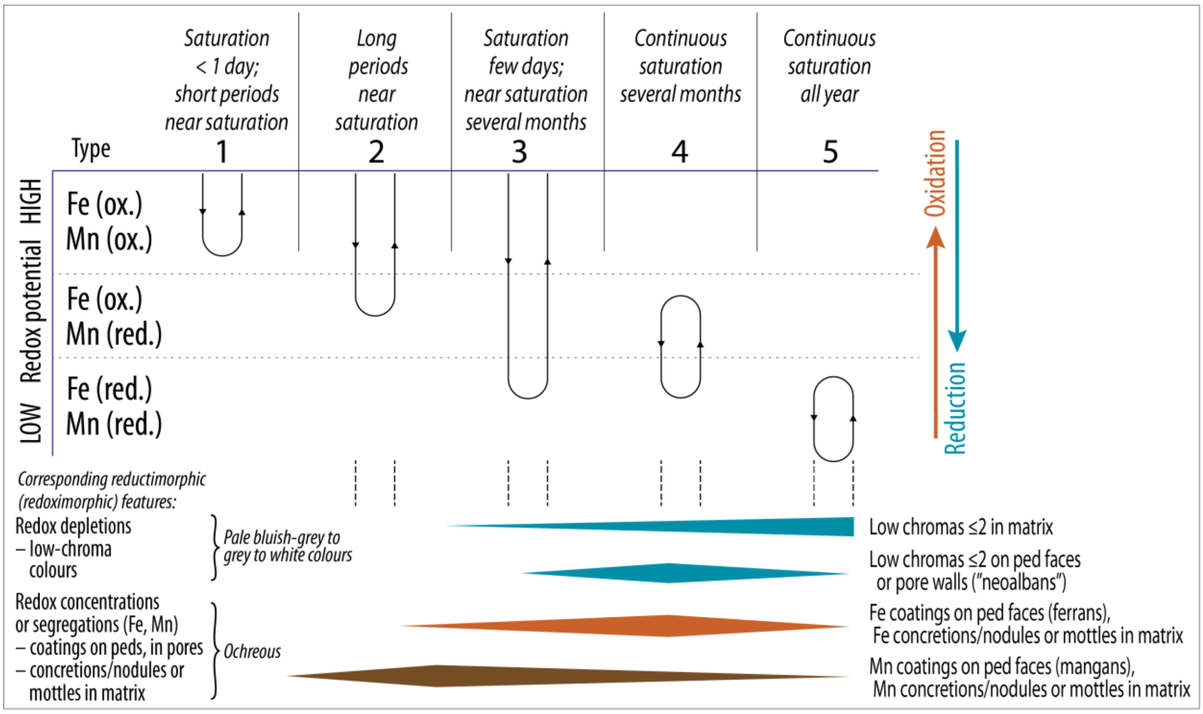

Figure 13. The approximate period of soil saturation in relation to the soil's oxidation/reduction state (upper part of diagram) and the morphological features (soil colour and presence of iron and manganese coatings, concentrations, segregations, or nodules) indicating gleying (lower part of the diagram). Adapted from Hewitt et al., 2021, modified after Bouma, 1983. Reducing conditions can be tested using the Childs' test for Fe2+ (Childs, 1981).

Abundance of redoximorphic features

Estimate the percentage of redoximorphic features using the abundance charts in section 6 of this handbook (Figure 15) or in Appendix 2 in Milne et al. (1995). Use Table 23 to find the correct abundance class code and record this on the scoresheet.

*If no mottles are present, indicate **N** on the scoresheet.*

Table 23. Abundance of mottles (Milne et al., 1995, p. 97)

CODE	CLASS	ABUNDANCE (%)
1	Very few	<2
2	Few	2<10
3	Common	10<25
4	Many	25<50
5	Abundant	50<75
6	Profuse	>75

Contrast of mottles

Consider the most abundant redoximorphic colour along with the relevant soil matrix colour to determine mottle contrast using Table 24. *Record the result on the scoresheet; if no mottles are present, mark as **X**.*

Table 24. Contrast classes of redoximorphic features.

CODE	CLASS	DEFINITION
F	Faint	Indistinct colour variation evident on close examination. Typically the mottle colour is of the same hue and will differ by no more than one unit of chroma or two units of value.
D	Distinct	Although not striking, the colour variation is readily seen. Matrix and mottle colours usually: • have the same hue but differ by 1<4* units of chroma, or 2<4 units of value. Or, • differ by 1 hue (2.5 Munsell units) and <2 units of chroma, or <3 units of value.
P	Prominent	The colour variation is conspicuous. Matrix and mottle colours usually differ by: • ≥2 hues (5 Munsell units) if chroma and value are the same. Or, • ≥4 units of value or chroma if hue is the same. Or, • ≥1 unit of chroma or ≥2 units of value if there is a difference of only 1 hue (2.5 Munsell units).

* Notations such as ‘1<4’ mean greater than 1 and less than 4, excluding both 1 and 4. Although this may sometimes appear to imply only one possible value (e.g., ’2<4’ seeming to mean just 3), half units in the colour book are also included in this range.

2.7 Coatings

Coatings refers to features that appear on ped and void surfaces.

*Using Table 25, determine the type of coatings and record the code on the scoresheet. If no coatings are present, indicate **X** on the scoresheet.*

Table 25. Classification of types of coatings (adapted from Milne et al., 1995, p. 74; with additions from Schoeneberger et al., 2012).

CODE	CLASS	DEFINITION
X	No coatings	No coatings present
CB	Carbonate coats	They may be coats of powdery material or concentrations of larger crystals. (Mainly calcium carbonates.)
CC	Clay coats (argillans)	Waxy, exterior coats. Often different in colour from matrix. Usually recognizable in sandy/loamy soils, hard to recognize in clayey soils where they can be undistinguishable from pressure faces.
OG	Organic coats	Dark, organic stained films with a moist value of ≤4 and rich in organic matter in comparison to the interior of the coated solid.
SQ	Sesquioxide coats	Films of sesquioxides, often ferri-manganiferous coats. Normally very dark brown or black to blue-black. Gives brown streak
SS	Slickensides	Smooth/glossy faces with linear grooves/striations on soil-structural units (peds). Caused by shrinking and swelling leading to lateral movement of adjoining peds on wetting.

3 Soil Profile Characteristics

The following soil profile characteristics must be determined:

3.1 Effective soil depth and restrictive layer
3.2 Hydraulic conductivity of surface layer and restrictive layer
3.3 Available Water Holding Capacity
3.4 Soil Drainage Class

3.1 Effective soil depth & restrictive layer

Effective soil depth

Determine the effective soil depth category using Table 26 and record the correct code on the scoresheet.

Effective soil depth is the depth to:

- a restrictive layer (defined in Table 27), **or**
- a Very Stony horizon (more than 35% stones by volume), **or**
- the maximum depth specified for description in the soil judging competition.

Table 26. Effective soil depth classes (S-Map, 2022).

CODE	CLASS	DEPTH TO RESTRICTIVE LAYER
D	Deep	≥ 100 cm
MD	Moderately deep	50 ≤ 100 cm
S	Shallow	20 ≤ 45 cm
VS	Very shallow	< 20 cm

Type of restrictive layer

Determine the type of restrictive layer using on Table 27 and record the correct code on the scoresheet.

Table 27. Type of restrictive layers.

CODE	CLASS
BR	Bedrock
FI	Very firm or harder consistence OR, Fim consistence combined with massive soil structure
CS	Structureless ZC, C or SC
CM	Massive ZC, C or SC
W	Reducing conditions or water table
IM	Impermeable Layer
N	No restrictive layer

3.2 Hydraulic conductivity

Saturated hydraulic conductivity plays a key role in soil hydrology and the soil's capacity to support crop production and agricultural processes.

Estimate the hydraulic conductivity class of the ***surface layer*** ***and*** ***of the restrictive layer*** *using Table 28. Record the correct class codes (H, M or L) on the scoresheet.*

Table 28. Hydraulic conductivity classes.

CODE	CLASS	DEFINITION
H	High	• All sand and loamy sand texture classes. • Sandy loam, sandy clay loam, and silt loam texture grades that are especially 'loose' because of very high organic matter content (>5% organic carbon). • Horizons containing >60% of coarse fragments with insufficient fines to fill voids between fragments are also considered to have high hydraulic conductivity.
M	Moderate	Materials excluded from 'low' and 'high' classes.
L	Low	• Clays, or silty clays having structure grade of **M** or **W**; or structureless (**X**) and massive (**MA**). • Clay loams that have a structure grade of **W**; or structureless (**X**) and massive (**MA**). • Bedrock layers (Cr or R horizons) where the horizon directly above contains redoximorphic depletions or a depleted matrix due to prolonged wetness (value ≥4 with chroma ≤2). • Bfm or Bx horizons or other restrictive pans.

3.3 Available water-holding capacity (AWHC)

Available water-holding capacity, crucial for agronomic assessments of crop growth, is approximately the water held between field capacity and permanent wilting point. The AWHC is calculated for the top 100 cm of the soil profile.

*Determine the **available water-holding capacity** of the soil, based on the information below.*

The total available water-holding capacity is calculated by summing the amount of water held in each horizon to a maximum depth of 100 cm. If there is a restrictive layer, the AWHC is calculated to the upper boundary of this restrictive layer. Similarly, if the lower depth for judging is less than 100 cm, the water content is calculated to this specified depth. If the depth of a horizon goes over 100 cm then the AWHC is calculated to 100cm.

The calculation

The relationship between available water retained per cm of soil and soil texture is presented in Table 29.

- Coarse fragments, for the purpose of this competition, are considered to have negligible (assume zero) moisture retention, and estimates must be adjusted to reflect the coarse fragment content. If a soil contains coarse fragments, the volume occupied by the rock fragments must be estimated, and the AWHC corrected accordingly.

Table 29. Simplified estimated relationships between available water holding capacity by texture class.

AWHC (cm water/ cm soil)	APPLICABLE TEXTURE CLASSES
0.05	S, LS
0.10	SL
0.15	SCL, CL, LC, C
0.20	LZ, ZL, ZC, Z

Example calculation:
Consider a **SILT LOAM** horizon that is **25 CM THICK** and contains **10% ROCK FRAGMENTS.**

The available water-holding capacity of the horizon would be calculated as follows:

Thickness (cm)	×	AWHC for ZL (cm/cm)	×	fine-earth fraction
(upper – lower boundary)		*(from Table 29)*		*[(100 - % coarse fragments)/100]*
25 cm or 250 mm	×	**0.20 cm/cm or mm/mm**	**×**	**[(100-10)/100]=4.50cm or 45mm**

Repeat this calculation for each subsequent horizon (rounding to 2 decimal points), up to 100 cm or restrictive layer (see notes above). Sum AWHC of all horizons and round total AWHC (mm) to 1 decimal point.

AWHC retention classes

Use Table 30 to determine the correct retention classes for AWHC (cm) and record the correct code on the scoresheet.

Table 30. AWHC retention classes (S-Map, 2022).

CODE	CLASS	PROFILE AWHC (mm)
VL	Very Low	< 30 mm
L	Low	30–59 mm
ML	Moderate to Low	60–89 mm
M	Moderate	90–119 mm
MH	Moderate to High	120–149 mm
H	High	150–249 mm
VH	Very High	> 250 mm

3.4 Soil drainage class

Soil drainage class is important for understanding how soil function effects flooding, partitioning of water, drainage, habitat, water purification, and construction. Soil drainage class reflects the rate at which water is removed from the soil by both runoff and percolation. Landscape position, slope gradient, infiltration rate, surface runoff, and permeability, are significant factors influencing the soil drainage class. Redoximorphic features, including concentrations, depletions, and depleted matrix colours, are the common indicators of prolonged soil saturation and reduction, and are used to assess soil wetness class.

Use Table 31 to determine the soil drainage class and record the correct class code on the scoresheet.

Table 31. Soil drainage classes (Milne et al., 1995, pp. 148-149).

CODE	CLASS	DESCRIPTIONS
WD	Well drained	- Soils that have no horizon within 90 cm of the mineral soil surface with > 2% redox segregations.
MWD	Moderately well drained	- Soils that have a horizon between 60 and 90 cm of the mineral soil surface with ≥ 50% low chroma mottles on cut faces or ped faces. OR - Soils that have a horizon between 30 and 90 cm of the mineral soil surface > 2% redox segregations.
ID	Imperfectly drained	- Soils that have between the 30 and 60 cm of the soil surface, but not within 15 cm of the base of the A horizon, ≥ 50% low chroma mottles on cut faces or ped faces, OR • Soils that have within either 15 cm of the base of the A horizon, or 30 cm of the mineral soil surface: o > 2% redox segregations, or o < 50% low chroma colours on cut faces or ped faces.
PD	Poorly drained	• Soils that have a distinct topsoil (Hewitt, 2010) and have ≥ 50% low chroma colours on cut faces or ped faces within either 15 cm of the base of the A horizon, or 30 cm of the mineral soil surface, OR • Soils that lack a distinct topsoil and have ≥ 50% low chroma colours on cut faces between 10 and 30 cm from the mineral soil surface.
VPD	Very poorly drained	• Soils that have an O horizon (but no F or H horizon) with an Er, Br, or Cr horizon immediately below. OR, • Soils that lack a distinct topsoil and have ≥ 50% low chroma colours on cut faces at > 10 cm from the mineral soil surface.

4 Interpretations of land use suitability

Using Table 32, Table 33, and Table 34, respectively, determine the landscape suitability classes for (a) irrigated pasture, (b) effluent discharge, and (c) blueberry production.
Record the suitability class code (1, 2, or 3) on the scoresheet.

Steps for landscape suitability class determination:

1. Start in the right-hand column of the tables.
2. Read down the right-hand column, checking the criteria.
    a. If one factor is met in the right-hand column, the suitability class is Unsuitable (code 3).
    b. If none are met, move one column to the left.
3. Read down the middle column, checking the criteria.
    a. If one factor is met in the middle column (after the right-hand column has been checked), the suitability class is Suitable (code 2).
    b. If none are met, move one more column to the left.
4. If none of the criteria are met in either the right-hand or middle column, the suitability class is Optimal (code 1).

Table 32. Criteria for irrigated pasture land use.

FACTORS	LAND SUITABILITY RATINGS: IRRIGATED PASTURE		
	CLASS 1–OPTIMAL	CLASS 2–SUITABLE	CLASS 3–UNSUITABLE
Slope class	01, 02, 03, 04, 05	06	07, 08, 09
Drainage class	WD / MWD	ID	PD / VPD
Topsoil depth (cm)	>10	<10	-
Texture class in thickest horizon in upper 20 cm	SL, SCL	Others	S, C
Depth to hard rock (cm)	>60	45<60	<45
Soil pH	6.0<7.0	5.0<6.0; 7.0<7.5	<5.0 / >7.5
Hydraulic conductivity restrictive layer	H	M	L
AWHC to 100 cm*	>15	5<15	<5

* Or to depth used for calculating available water holding capacity in section 3.3

Table 33. Criteria for effluent discharge land use.

FACTORS	LAND SUITABILITY RATINGS: EFFULENT DISCHARGE		
	CLASS 1–OPTIMAL	CLASS 2–SUITABLE	CLASS 3–UNSUITABLE
Slope class	01,02,03,04	05,06,07	08,09
Texture class in thickest horizon in upper 20 cm	ZL,CL,LZ	SCL, SL, Z	C, ZC, LC, LS, S
Most limiting structural horizon in top 80 cm	Moderate and strong block-like structure.	Weak structured block-like structure OR all prism & wedge-like structure.	All Structureless material OR platy or tablet-like structure OR coarse or larger sized structural units.
Depth to restrictive layer (cm)	>80cm	60–79cm	<60cm
Drainage class	WD, MWD	ID	PD, VPD
Hydraulic conductivity restrictive layer	M	H	L
AWHC to 100 cm*	VH, H, MH	M, ML	VL, L
Other factors	-	-	SOIL TYPE: Organic, Gley, Podzol, Granular Artificial drainage present (mole, tile, etc)

* Or to depth used for calculating available water holding capacity in section 3.3.

Table 34. Criteria for blueberry production land use

FACTORS	LAND SUITABILITY RATINGS: BLUEBERRY PRODUCTION		
	CLASS 1–OPTIMAL	CLASS 2–SUITABLE	CLASS 3–UNSUITABLE
Slope class	01,02,03,04	05,06	07,08,09
Soil drainage class	WD	MWD, ID	PD, VPD
Texture class in thickest horizon in upper 20 cm	SL, SCL, SL, LS, LZ	CL, S, Z	LC, ZC, C
Topsoil pH	4.0–5.3	5.4–7.0	< 4.0 or > 7.0
Depth to restrictive layer (cm)	>40 cm	40–25 cm	<25 cm
Topsoil organic carbon %	>4.0%	2.0–3.9%	<2.0%

5 Diagnostic criteria and Soil Classification

The New Zealand Soil Classification (NZSC; Hewitt, 2010) is a hierarchical classification based on measurable soil properties, which allows the field assignment of soils to classes. At its highest level, the NZSC is divided into 15 soil Orders (Figure 14), and further divided into Groups and Subgroups. These levels are equivalent to Order, Suborder, and Great Group levels of both “Soil Taxonomy” and “Australian Soil Classification” schemes. The NZSC Subgroups can be further divided into Families and Siblings; however, these lower divisions will not be used in this competition.

Chemical and physical data required for soil classification will be provided at each pit.

5.1 Diagnostic Criteria

Includes horizons, pans, layers and features, soil material, contacts and profile forms.

On the scoresheet, clearly circle ALL the diagnostic horizons, pans, layers and features applicable to the profile within the specified description depth.

For detailed information on the diagnostic horizons and other differentiae, see pages 15-34 of NZSC (Hewitt, 2010). **Note:** the presence of allophanic soil material (a diagnostic horizon), likely to be important for well drained tephra-derived soils, can be identified using the reactive-aluminium test (Table 35; see Hewitt, 2010, pp. 30-31).

5.2 Soil classification

Order

Use pages 35-40 of the Key to Soil Orders (see black indicator tab on edge of pages) in NZSC (Hewitt, 2010) to determine ONE correct soil ORDER. Record this on the scoresheet.

Group

Using the pages applicable for Groups within the selected Order determine ONE correct GROUP. Record this on the scoresheet.

Subgroup

Using the pages applicable for Subgroups within the selected Order and Group determine ONE correct SUBGROUP. Record this on the scoresheet.

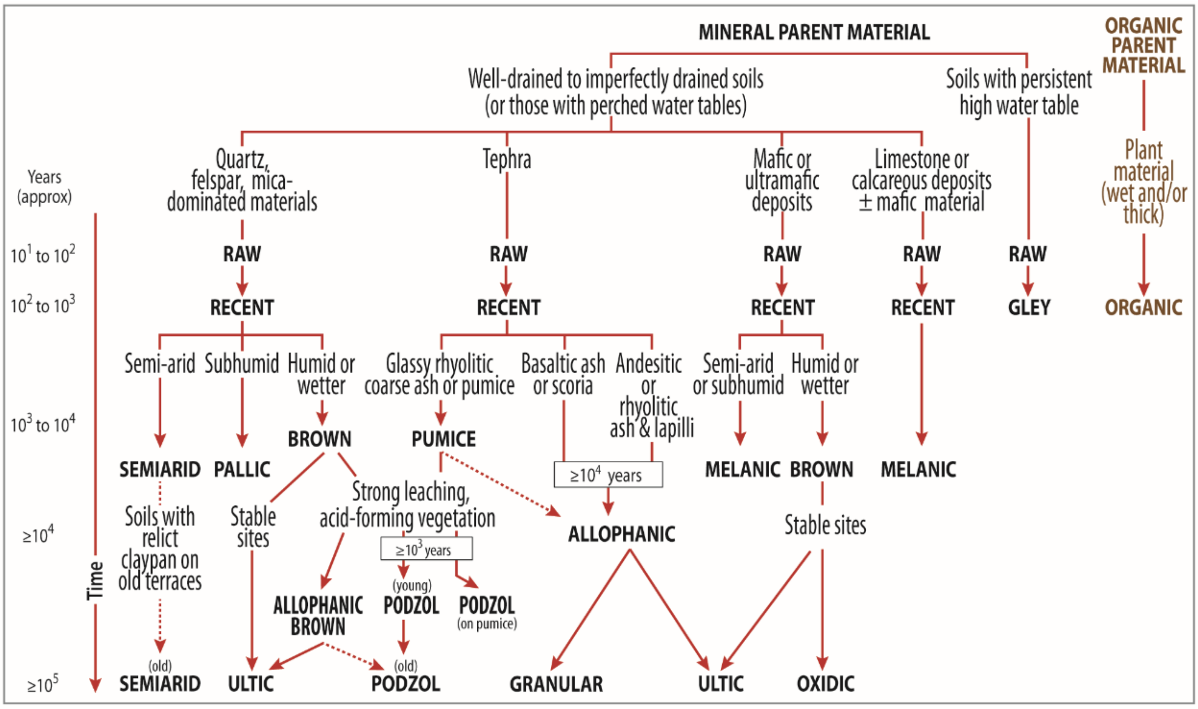

Figure 14. Major genetic pathways in the evolution of New Zealand soils in the framework of NZSC with approximate age ranges for their formation (from Hewitt et al., 2021).

Table 35. Classes of reactive aluminium test (NaF test for allophane) and associated approximate phosphorus (P) retention (after Hewitt, 2010).

Reactivity Class		*Class Definition*	*P retention*[1]
0	non-reactive	No colour within 2 minutes.	< 30%
1	very weak	Pale red or light red (5R 6/1) just discernible within 2 minutes.	
2	weak	Pale red or light red (5R 6/1) within 1 minute.	
3	moderate	Red or weak red (5R 4 or 5/-) within 1 minute.	≥ 30%
4	strong	Dusky red or dark red (5R 3/-) after 10 seconds.	≥ 85%
5	very strong	Dusky red or dark red (5R 3/-) within 10 seconds.	

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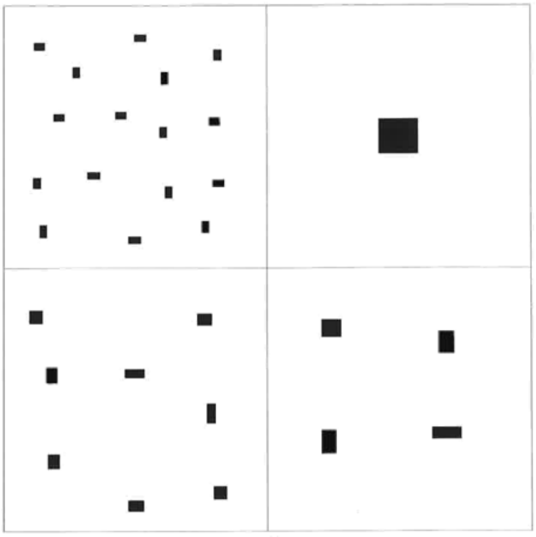
[1] Approximate phosphate retention class based on Hewitt (2010)

6 Abundance charts



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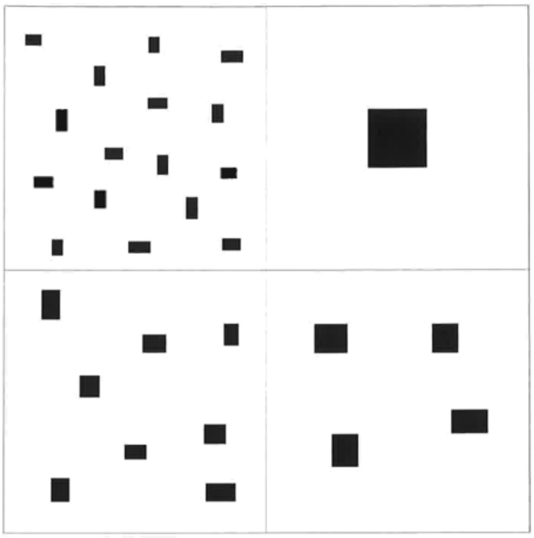

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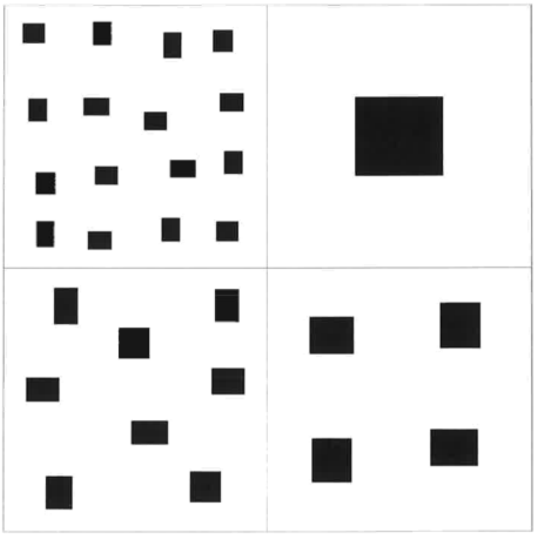

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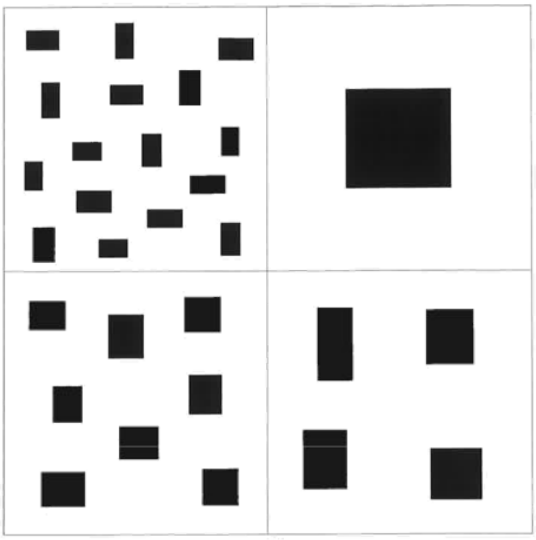

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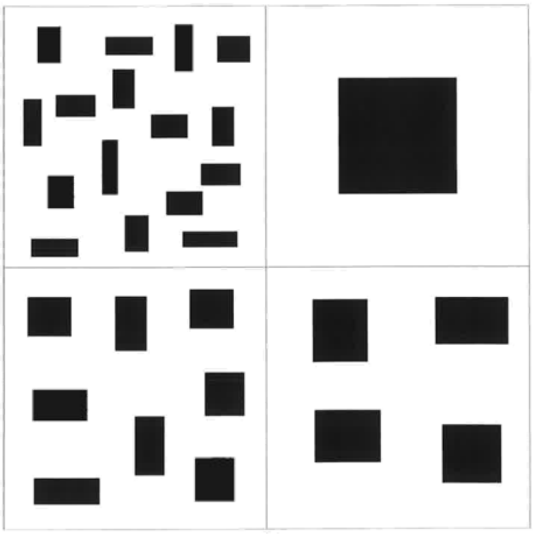

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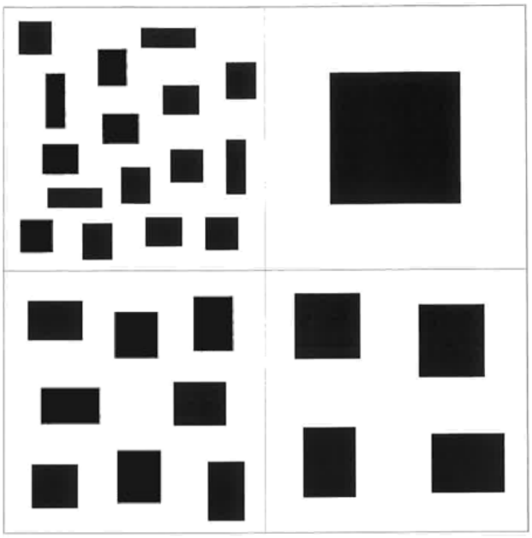

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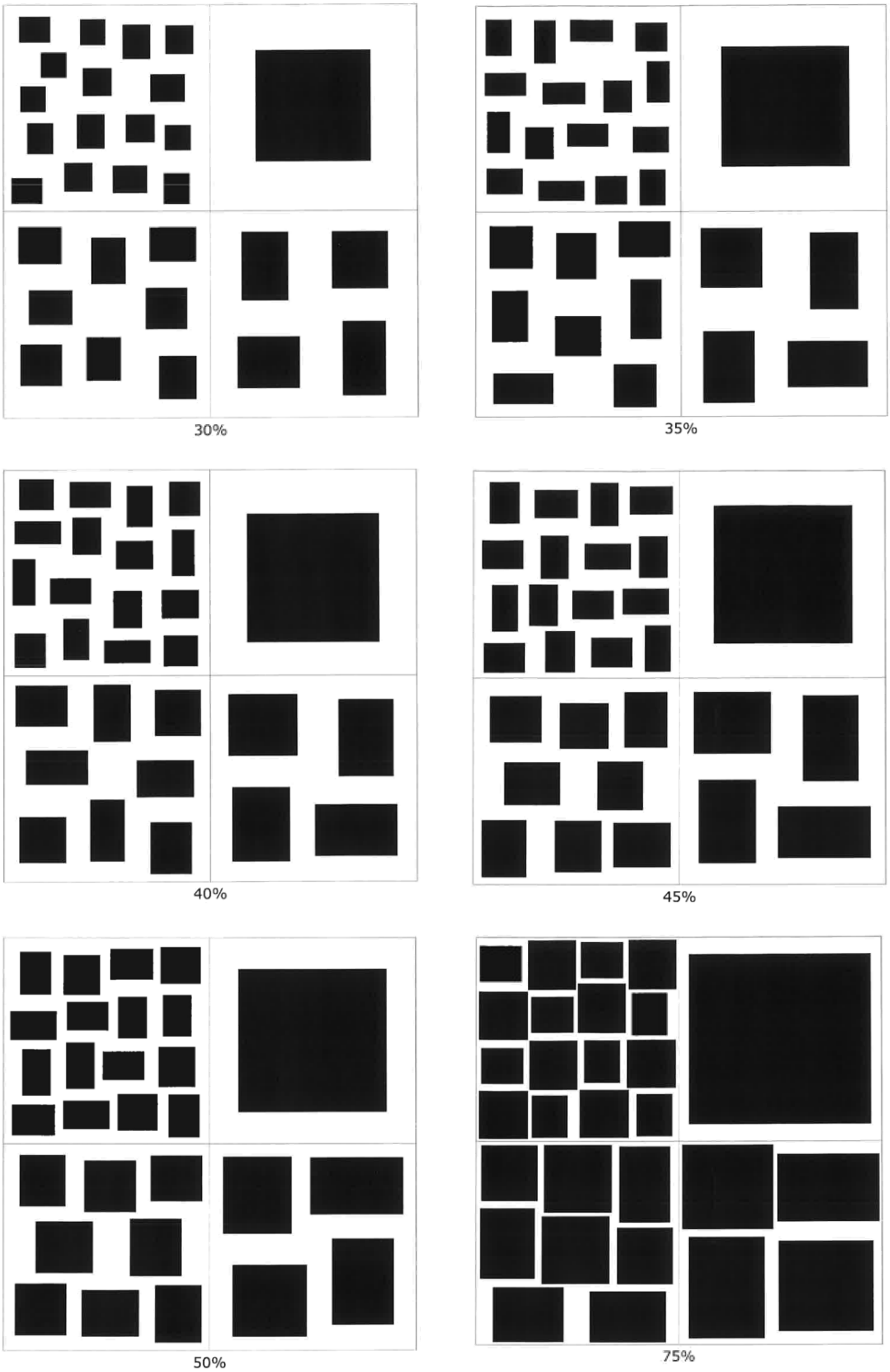

Figure 15. Abundance charts (Schoeneberger et al., 2012).

7 Appendix 1

Geology meets pedology: notes on terms and concepts for layered soil profiles, and associated paleosols, in volcanic terrains

Much of central North Island, including the Rotorua area (which lies within the central Taupo Volcanic Zone), has been repeatedly overwhelmed or modified by the emplacement of ignimbrites and numerous mantling tephra-fall deposits.

The terms ‘ignimbrite’ (the product of a pyroclastic flow), and ‘tephra’ (comprising all the explosively erupted, unconsolidated, fragmental [pyroclastic] products of a volcanic eruption), are defined in Table 36. Derivatives of the term tephra, including tephrochronology, tephrostratigraphy, and tephrochronometry (note the connecting vowel ‘o’, replacing ‘a’), are also defined in Table 36. One, or more, tephras are likely to provide the parent materials for many of the soils and paleosols in the area of study for the competition.

In locations proximal to the source, relatively thick deposits buried, and isolated, the antecedent soils. At medial and distal sites, relatively thin tephra-fall deposits tended to generate ‘accumulating’ profiles (Hopkins et al., 2021). The resultant tephra-derived soils comprise four distinct taxonomic classes in the New Zealand Soil Classification (Hewitt, 2010), and occur in a predictable spatial and temporal pattern (Lowe and Palmer, 2005; see supplementary notes):

1. (Tephric) Recent Soils
2. Pumice Soils
3. Allophanic Soils
4. Granular Soils

These soils are very important because they cover ~31% of North Island, and ~13.5% of New Zealand (Hewitt et al., 2021). Their character relates mainly to their mode of formation – upbuilding pedogenesis – along with composition and age (Lowe and Palmer, 2005).

A distinctive feature of many tephra-derived soils is the multilayered nature of their profiles, which attests to building up the landscape via the deposition of tephras from numerous eruptions. Therefore stratigraphy, or the study of geological layers and their ages, becomes essential in the description and understanding of the tephra-derived soils. These geological and pedological aspects combine to form *soil stratigraphy* or *pedostratigraphy* (Palmer et al., 2025). Pedostratigraphy is the study of the stratigraphic and spatial relationships of layered soils, both surface (modern) soils and buried paleosols, as well as the implications of these sequences/soils for understanding past environments through time. A paleosol is a soil, or soil horizon, formed on a landscape of the past (non-buried paleosols are formed in an environment of the past) (Palmer et al., 2025).

The sections and profiles exposed for the soil judging competition reflect the interplay of both geological and pedological processes, and the difference between these must be appreciated. *Geological processes* include the deposition of loess, alluvium, colluvium, or tephra deposits; *pedological processes* include the formation (genesis) of soil horizons via ongoing processes (driven by organic and hydrological cycles) acting on materials at, or near, the land surface, termed *topdown pedogenesis* (Palmer et al., 2025). The pedologist needs to firstly establish the stratigraphy (geological layering) and then evaluate the soil horizonation (see section 2.1). Some maps of the tephra-derived soil pattern of central and northern North Island, and a table listing the main tephras present in the Rotorua region, as well as their origins (volcanic source) and ages (since c. 25,400 cal yr BP), are provided in the supplementary notes.

Table 36. Tephra-related nomenclature*

Term	Definition and origin
Tephra	Explosively erupted, pyroclastic (fragmental) products of a volcanic eruption encompassing all grain sizes[1] and compositions irrespective of emplacement mechanism, i.e. a collective term for pyroclastic deposits predominantly unconsolidated or loose (from Greek *τέφρα* [*téphra*], 'ash', 'ashes').
Cryptotephra	Explosively erupted, fine-grained glass-shard and/or crystal concentration preserved in sediments (including ice) or soils/paleosols but insufficiently numerous, or too fine, to be visible as a layer to the naked eye (from Greek *κρυπτός* [*kryptós*], 'hidden', 'secret').
Tephrochronology *(sensu stricto)*	Use of primary tephra layers (or cryptotephras) as isochrons[2] to connect and date depositional sequences or events, or soils/paleosols, using stratigraphy and compositional 'fingerprints' and other data, i.e. an age-equivalent method of transferring relative or numerical ages from site to site.
Tephrochronology *(sensu lato)*	All aspects of tephra/cryptotephra studies and their application.
Tephrochronometry	Obtaining a numerical age[3] or calendrical date[3] for a tephra layer or cryptotephra deposit.
Tephrostratigraphy	Study of sequences of tephra or cryptotephra deposits (and associated materials), their lithologies, distribution, and stratigraphic relationships, and relative and numerical ages; involves defining, describing, characterizing, and mapping tephra/cryptotephra deposits via field and laboratory work, and potentially obtaining numerical ages/dates for them.
Pyroclastic	Explosively erupted fragmental (loose) volcanic material that on deposition may remain predominantly unconsolidated **(= tephra)**, or become consolidated (hardened) via welding or cementation **(≠ tephra)** (*pyroclastic* = 'firey fragments'). *Pyroclasts* are the individual crystals, crystal fragments, glass fragments, and rock (lithic) or pumice fragments or clasts generated by explosive volcanic action.
Ignimbrite	The product of a pyroclastic flow or density current which may be non-welded (i.e. loose, unconsolidated) or welded[4] to form a rock (*ignimbrite* = 'firey storm-cloud')

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*Mainly after Lowe (2011) (see also Alloway et al., 2025).

[1] Volcanological grain-size definitions: ash <2 mm; lapilli 2–64 mm; blocks & bombs >64 mm.

[2] Tephras are erupted and deposited over very short time periods, usually only hours or days to perhaps weeks or months, forming a thin, wide-spread blanket that (unless reworked) has the same age (isochronous) wherever it occurs. Once identified by its physical, mineralogical, and geochemical properties, a tephra layer thus provides an isochron, or an 'instant' in time, that instant being the date of the eruption that produced the layer.

[3] Ages are reported using calendar (cal) years before present (BP). In the radiocarbon (^{14}C) timescale, 'present' is 1950. Ages in ^{14}C years are converted to calendar years using calibration curves because the amount of ^{14}C in the atmosphere has not been constant. An 'age' is a period before present, usually reported in cal years BP (e.g., 14,000 cal yr BP) or cal ka (ka = 1000 years BP) (e.g. 14 cal ka). In contrast, a 'date' is a point on a calendrical timescale (e.g. 1886 AD/CE).

[4] Some ignimbrites are hot enough (>550° C), especially after they have flowed into valleys and thickened, for pumice fragments and glass shards to sinter (melt into one another) under compactional loading in a process known as welding, producing weakly or partially or densely welded hard rock (e.g. 1.3 Ma Ongatiti ignimbrite, quarried as Hinuera Stone). Other ignimbrite deposits, usually thinner and cooler, remain as loose or non-welded ignimbrites in which pumice fragments can be plucked out by hand (e.g. 1.8 cal ka Taupo ignimbrite).

Upbuilding pedogenesis

Most soil textbooks describe only the 'classical' formation of soil horizons, where a profile gradually deepens through various processes as a downward moving 'front'. This occurs within a pre-existing parent material that occurs on a stable land surface with nil (or negligible) additions to the surface. Such soil formation (pedogenesis), referred to **as *topdown pedogenesis,*** proceeds by effectively modifying a pre-existing parent material to a greater or lesser extent, and according to factors that dictate a range of processes and their impacts. In this situation, the soil profile originates via a two-step process: step 1, accumulation (or exhumation) of a fresh parent material at the land surface, followed by step 2, the modification of the parent material by soil-forming processes and weathering to form soil horizons, thus generating a soil profile.

In North Island landscapes, however, where tephras have been repeatedly deposited (noted earlier), many of the soils are formed by ***upbuilding pedogenesis****.* This is the ongoing formation of soil via topdown processes whilst tephras (or loess, alluvium, etc) are simultaneously added to the land surface. The pivotal concept is concurrent deposition and pedogenesis. In this scenario, step 1 and step 2 occur together (not sequentially) so that the soil profile deepens as the land surface rises concomitantly over time.

The frequency and thickness of tephra accumulation, and other factors, determine how much impact topdown processes have on the ensuing soil-horizon development and profile character. Two 'end members' can be identified, designated (1) *retardant* vs. (2) *developmental* upbuilding.

1. ***Retardant upbuilding*** occurs either when a relatively thick layer (e.g. ~50 cm or more) of tephra (or alluvium, colluvium, etc) is instantaneously added to the surface, or, when the rate of accumulation of thinner additions is exceptionally fast, so that the original soil is rapidly buried, thus becoming a buried soil (or horizon) that is cut off and isolated from surface processes (Figure 16). Pedogenesis begins anew on the fresh materials at the new land surface. This process is called 'retardant' because the original soil's development has been permanently retarded by its sudden/rapid burial.
2. ***Developmental upbuilding*** occurs when the rate of addition of tephra (or loess) to the land is incremental and sufficiently slow for topdown pedogenesis to effectively keep pace as the land gradually rises. Topdown pedogenesis continues whilst thin tephras and cryptotephras accumulate but its impacts are lessened because any one position in the sequence is not exposed to surface dominated pedogenesis for long before it becomes buried too deeply for these processes to be effective (Figure 16;

> Hewitt et al., 2021). Thin tephra layers preserved in sediments of nearby lakes or bogs provide unequivocal evidence of persistent incremental tephra accretion to adjacent soil/land surfaces (Figure 17and Figure 18). This history thus leaves the entire profile with a weakly-weathered soil fabric, inherited from when the tephra deposits were being modified at the surface as part of an A horizon and/or upper subsoil (AC, AB, or Bw) horizons.

The terms ‘developmental’ and ‘retardant’ upbuilding were coined by Johnson and Watson-Stegner (1987) and Johnson et al. (1990) as part of their dynamic-rate model of soil evolution whereby soils are envisaged to evolve by ‘ebb and flow’ through time (Schaetzl and Thompson, 2015; Palmer et al., 2025).

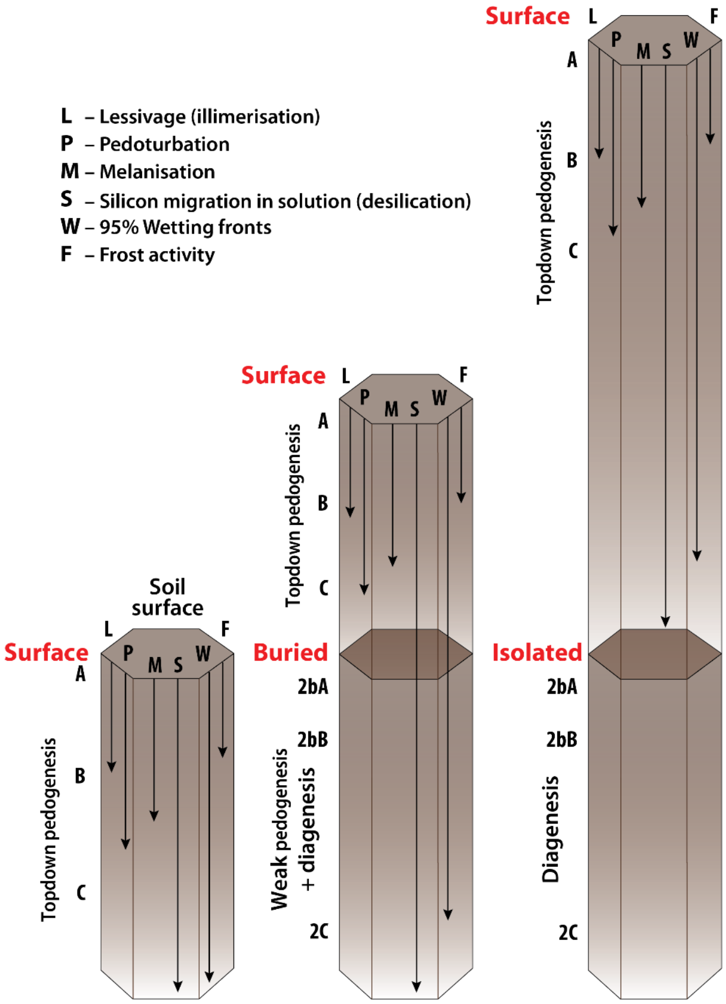

Figure 16. Idealized model of the relative depth of burial of paleosols and their alteration by pedogenic processes acting from the surface downwards (arrows). Once a paleosol is isolated by relatively deep burial, any changes may be regarded as largely diagenetic, not pedogenetic (from Churchman and Lowe, 2012, modified after Schaetzl and Sorenson, 1987).

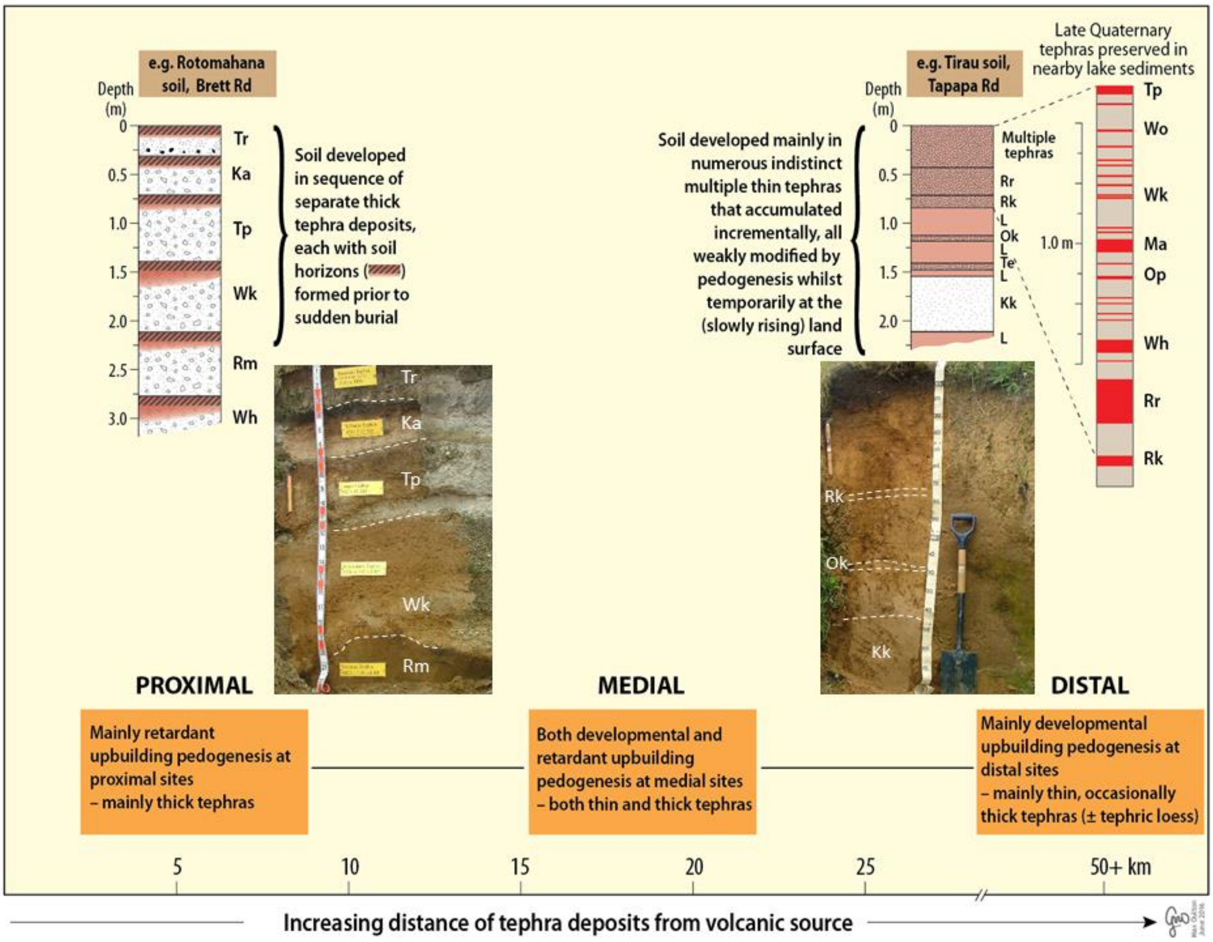

Figure 17. Diagram illustrating the difference between retardant upbuilding pedogenesis (Rotomahana soil at left) at Brett Rd versus mainly developmental upbuilding pedogenesis (Tirau soil at right) at Tapapa Rd, western Mamaku Plateau, and how these differences relate generally to tephra thickness and distance of site from volcanic sources. Tephra thicknesses usually decline exponentially away from source. Stratigraphy is after Huang et al. (2021). Tephra abbreviations and ages: Tr, Tarawera (Rotomahana Mud) (10 June 1886); Ka, Kaharoa (1314 ± 12 AD/CE); Tp, Taupo (232 ± 10 AD/CE); Wo, Whakaipo (c. 2.8 cal ka); Wk, Whakatane (c. 5.5 cal ka); Ma, Mamaku (c. 7.9 cal ka); Op, Opepe (c. 10.0 cal ka); Rm, Rotoma (c. 9.4 cal ka); Wh, Waiohau (c. 14.0 cal ka); Rr, Rotorua (c. 15.6 cal ka); Rk, Rerewhakaaitu (c. 17.5 cal ka); Ok, Okareka (c. 23.5 cal ka); Kk, Kawakawa (Oruanui) (c. 25.4 cal ka (see also Table S1 in supplementary notes). L = tephric loess.

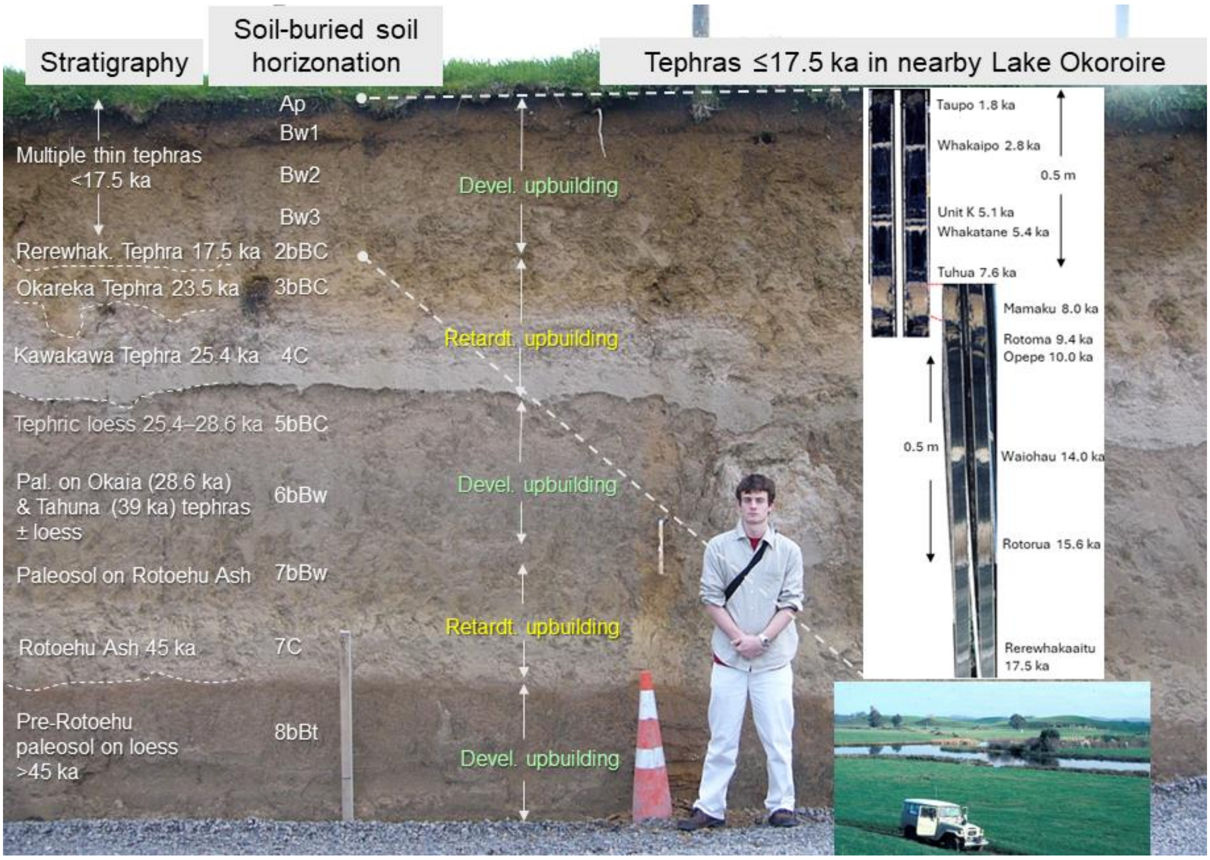

Figure 18. Section (on Leslie Road near Putaruru) showing the stratigraphy and soil horizons, including paleosols, associated with mainly rhyolitic tephras and tephric loess deposited over the last 45,000 cal years or more. Ages are in cal ka (Palmer et al., 2025). The modern soil (Tirau gritty silt loam) was formed mainly, but not wholly, by developmental upbuilding pedogenesis with numerous thin tephra-fall layers deposited incrementally since c. 17.5 cal ka providing its composite parent material. The inset panel at right shows the likely contributing tephra layers which are evident as thin (up to 10 cm) discrete layers preserved within organic sediments in two overlapping cores taken from nearby c. 20 cal-ka Lake Okoroire. The lake (inset photo lower right) is ~12 km from this section. The upper profle (above Rerewhakaaitu Tephra, Rk) is allophanic, reflecting currently warm, humid conditions (strong desilication favours allophane formation – see supplementary notes), and the lower profile (below Rk) is halloysitic, reflecting earlier cool, dry conditions (low desilication favoured halloysite formation) (Churchman and Lowe, 2012). Soil horizonation is based on Clayden and Hewitt (1989). The numeral prefixes indicate lithological discontinuities which are contacts of geological, not pedological, origin (Clayden and Hewitt, 1989) (see section 2.1). Here, the geological events specifically include the fall of new tephra deposits from volcanic eruptions and the onset and cessation of loess deposition. The prefix 'b' denotes an identifiable soil horizon with pedogenic features developed before its burial (i.e., when it was at or near the land surface). The sudden deposition of relatively thick Rotoehu Ash at c. 45 cal ka, and Kawakawa Tephra at c. 25.4 cal ka, buried the antecedent soil, and top-down soil formation began again on each of these new materials at the land surface, marking infrequent episodes of retardant upbuilding pedogenesis at this site (from Palmer et al., 2025, modified after Lowe and Palmer, 2005).

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Previous Soil Judging Competitions

Year	Location	Student/postgrad		Working Professional	
		Team Winners (Overall)	Individual Winner	Team Winners (Overall)	Individual Winner
2012	Hobart, TAS	University of Tasmania	Lisa Scholz (University of Queensland)	n/a	n/a
2013	No Competition	n/a	n/a	n/a	n/a
2014	Melbourne, VIC	University of Sydney	David Coleman (University of Sydney)	n/a	n/a
2015	Perth, WA	La Trobe University	James Manson (La Trobe University)	n/a	n/a
2016	Queenstown, NZ	University of Wisconsin-Platteville A	Rebecca McGirr (University of Sydney)	n/a	n/a
2017	Toowoomba, QLD	University of Sydney	Camilla Gardiner (Lincoln University)	n/a	n/a
2018	Canberra, ACT	University of Sydney		n/a	n/a
2018	Napier, NZ	Waikato University • Matthew House • Anne Wecking • Annette Carshalton	Ivanah Oliver (University of New England)	n/a	n/a
2019	Adelaide, SA	Southern Cross University	Lloyd Ryder (University of Sydney)	n/a	n/a
2020	Virtual Online (NZ & Aus)	Lincoln University • Kirstin Deuss • Sam Earl-Goulet • Louisa Hall	Apsara Amarasinghe (University of New England)	n/a	Ivanah Oliver (University of New England)
2020	Golden Bay, NZ	Lincoln University • Louisa Hall • Kirstin Deuss • Sam Earl-Goulet	Louisa Hall (Lincoln University)	n/a	n/a
2021	Cairns, QLD	University of New England	Chloe Lai (University of Queensland)	n/a	n/a
2021	Waipara, Canterbury NZ	Lincoln University • Louisa Hall • Julie Gillespie • Lucy Bell	Julie Gillespie (Lincoln University)	n/a	n/a
2022	Ballarat, VIC	University of Sydney	Lucinda Matthews (Univeristy of Melbourne)	n/a	Michael White (Landloch)
2022	Blenheim, NZ	Lincoln University • Julie Gillespie • Amy Wells • Meila Picard	Louisa Hall (Lincoln University)	• Dr Tapuwa Marapara (then Otago RC, now MfE) • Dr Hadee Thompson-Morrison (then ECAN, now MWLR) • Courtney Wright-Watson (University of Canterbury) • Alice Wheatley-Wilson (Waikato RC)	Dr Hadee Thompson-Morrison (then ECAN, now MWLR)
2023	Darwin, NT	University of Melbourne & Monash University	Carys Luke (Lincoln University)	n/a	Michelle Papenfus (SLR Consulting)

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NOTES

NOTES


Rotomahana 10 June 1886 (~3.20-6.00 am)
Kaharoa AD 1314 ± 12 (winter)
Rotoma 9423 ± 120 cal yr BP
Waiohau 14,009 ± 155 cal yr BP
Wh
Rotorua
15,635 ± 412 cal yr BP

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