ANDEYSEZ 57 KARREN

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In memory of Ken Grimes

Strangely enough I haven't done an ANDYSEZ on karren – one of my favorite aspects of karst landscapes – the small features. Well in the tropics, as we saw recently at the wonderful Capricorn Caverns, they can be quite big features. And this is going to be a big ANDYSEZ. Thanks to those who contributed images.

Ken Grimes was an exceptional scientist, bushman, communicator, teacher and, above all, a thorough gentleman, well known across Australia and around the world for his understanding and documentation of karst.

In the four or more decades that I worked with Ken I only saw him out of sorts once – and I was fully in agreement with his crossness on that occasion. A few days before Ken's tragic death we communicated by email and we agreed that this would be a joint production. Unfortunately, that was not to be. It would have been far, far better production with his input.

This has been a very difficult ANDYSEZ to write for other, less important reasons. When I start to google 'karren' I get screens full of images of ladies. Whilst not altogether unpleasant it distracts from the task at hand! Particularly annoying is the fact that MSWord won't allow you to add 'karren' to the dictionary so this document is full of green underlinings!

Karren is a 'portmanteau' term (younger people may need to google that word as I assume dictionaries are passé – you might have to check that too) to describe small to medium scale landform features produced by solution of surface and subsurface bedrock – chiefly limestone but other rocks such as dolomite, gypsum and halite (salt). Karren features occur on other rock types but we will avoid them here. For now … Maybe that will be a further ANDYSEZ.

Karren features are normally dismissed in a few paragraphs or short chapters in karst geomorphology texts. However, I am in possession on a text book titled Karst Rock Features: Karst Sculpturing edited by Ginés, Knez, Slabe and Dreybolt (2009, published by the Karst Research Institute, Postojna, Slovenia) It is a mere 561 pages long! And three (3) cm thick excluding the hard covers! The references alone run to about 26 pages! About 750 papers or books referenced! Clearly there is more to karren than we normally think about. There are probably only two copies of this book in Australia – it could be borrowed from me but only under the strictest conditions – it was a dying gift from Elery Hamilton-Smith and is thus is a very precious item. The other copy would be Ken's.

The book consists of two major parts – the first deals with the different types of karren in 20 chapters. The second part consists of 23 case studies including two from Ken. Then there are all the references – but no index. But help is at hand – there is a separate index – I think produced by Ken. But I don't know where it might be found. I had a suspicion that the book might be available online but I can't find a source at present.

Angel Ginés, in his Chapter 1 in the book cited above, has some nice things to say about karren so I will quote from his chapter (Karrenfield Landscapes and Karren Landforms). On page 19 he states:

> *Karren is a complex group of small to medium-sized karstic landforms showing a great variety of characteristic shapes. Some of them can be considered as elementary karren features, since they seem associated to definite genetic factors and they frequently become integrated in wider-scale karren assemblages.* ***The bewildering diversity of karren is difficult to summarize.*** [Emphasis mine]

Karren features are small scale karst landscape features produced by solution on limestone and other rocks where rain water charged with atmospheric carbon dioxide is acidic and thus is able to corrode (dissolve) the bedrock. This is the same process that gives us our caves.

Most of the initial research and description of karren was by German researchers so we have terms like rillenkarren, rundkarren, kamanitzas and spitzkarren to cope with. There are English equivalents for many and Angel Ginés and I will discuss and illustrate some of these below. Quotes from Ginés are in plain text – my comments in non-bold italics. We discuss many of the 25 types he identifies in his chapter. But it must be emphasised that many forms merge into one another so there can (will) be an almost chaotic assemblages – as we could see at Capricorn Caverns.

But first I must define epikarst for you. Michel Bakalowicz (2014) in a paper titled *The Epikarst, The Skin of Karst* (pp 16-22, Karst Waters Institute Special Publication 9, Leesburg, Virginia) states:

> *The epikarst is the shallow, superficial part of karst areas, in which climate, tree roots and karst processes fracture and enlarge rock joints and cracks, creating a more permeable zone overlaying the massive carbonate rock in which only few open vertical joints and fine cracks occur* (page 17).

Paraphrasing Madeline Schreiber and others (2015), *Instrumenting Caves to Collect Hydrologic and Geochemical Data: Case Study from James Cave, Virginia*:

> *The epikarst is a critical zone that significantly influences karst hydrology, [cave formation], water quality, and ecosystems. The epikarst controls both the quantity and quality of internal recharge to karst aquifers and, as a result, is a particularly important component of the system* (page 205).

From: https://www.researchgate.net/publication/291957042_Instrumenting_Caves_to_Collect_Hydrologic_and_Geochemical_Data_Case_Study_from_James_Cave_Virginia

Karren is the 'upper skin' of the epikarst and provides the collection surfaces and initial conduits that get the water into the epikarst and the karst proper.

Angel Ginés, in a 2005 personal communication to Ken, laid out some size criteria for thinking about karren as follows:

- Macrokarren: Large-sized karren – recognisable within a 10 m grid (pinnacles, giant grikes, etc.).
- Mesokarren: Normal-sized karren – recognisable within a 1m grid (rillenkarren, kamenitza, etc.).
- Microkarren: Small-sized karren – recognisable within a 1cm grid. (rillensteine, etc.)
- Nanokarren: Minute features – recognisable under magnification within a 1mm grid.

The first three will be discussed here - we won't worry about nanokarren here – too small for your visitors to appreciate easily!

Ginés, in his Table 1, provides a classification of karren forms leading from elementary features to the more complex assemblages. The classification provides further subdivisions by size and a higher resolution than that shown above.

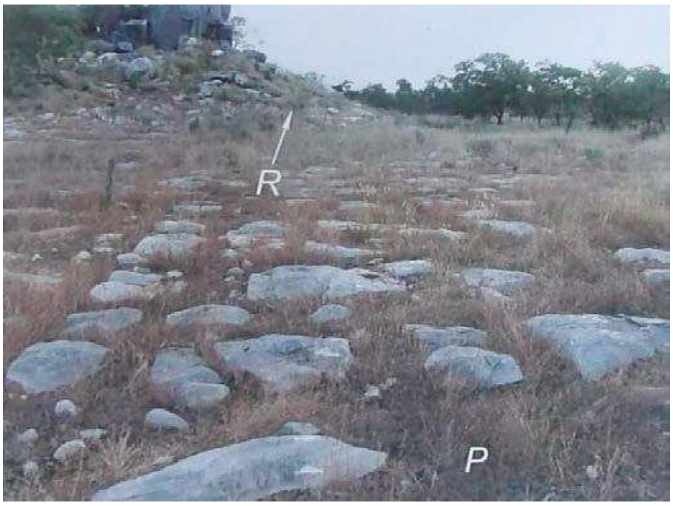
Table 1: Classification of karren forms. Yellow areas enclose elementary karren features. Green areas enclose complex large-scale landforms, namely karren assemblages and karrenfield types (after Ginés 2004, slightly modified).

SOLUTIONAL AGENT	KARREN FORMS								SYNONYMS
BIOKARSTIC	BORINGS								
WETTING		IRREGULAR ETCHING							
TINY WATER FILMS		MICRORILLS							RILLENSTEINE
STORM SHOWERS			RAINPITS						SOLUTION PITS
DIRECT RAINFALL				RILLENKARREN					SOLUTION FLUTES
CHANELLED WATER FLOW					SOLUTION RUNNELS				RINNENKARREN
						WALL KARREN			WANDKARREN
					DECANTATION RUNNELS				
					MEANDERING RUNNELS				MÄANDERKARREN
STANDING WATER				KAMENITZAS					SOLUTION PANS
SHEET WASH WATER FLOW				SOLUTION BEVELS					AUSGLEICHSFLÄCHEN
				TRITTKARREN					HEELSTEPS
		COCKLING PATTERNS							
			SOLUTION RIPPLES						
SNOW MELTING				TRICHTERKARREN					FUNNEL KARREN
				SHARPENED EDGES					LAME DENTATES
					DECANTATION RUNNELS				
					MEANDERING RUNNELS				MÄANDERKARREN
ICE MELTING						MEANDERING RUNNELS			
INFILTRATION					GRIKES				KLUFTKARREN
SOIL PERCOLATION WATER					RUNDKARREN				ROUNDED RUNNELS
				SMOOTH SURFACES					BODENKARREN, SUBCUTANEOUS KARREN
				SUBSOIL TUBES					
				SUBSOIL HOLLOWS					
					CUTTERS				
COMPLEX PROCESSES					UNDERCUT RUNNELS				HOHLKARREN
					CLINTS				FLACHKARREN
					PINNACLES				SPITZKARREN
							PINNACLE KARRENFIELD		KARRENFELD
							LIMESTONE PAVEMENT		
								STONE FOREST	
								ARÊTE KARST	
	0-1mm	1mm-1cm	1-10cm	10cm-1m	1m-10m	10-100m	100m-1km	1km-	LAPIÉS

Table 1. Classification of karren forms. From Ginés, page 16.

Pavements: These are not in Angel's list but are a very characteristic karst landform. However, they are not well-discussed in the literature. One can easily come across definitions such as 'horizontal surfaces of exposed limestone in which the joints have been enlarged, cutting the surface into roughly rectangular blocks'. Most texts point to their origin arising from glacial action – but this is impossible in the case of Chillagoe and Kongorong (see the accompanying images). Various chapters in Ginés et al (2009) touch on pavements without adding much to the discussion. One author states that there are five types – but all arise from glaciated surfaces subsequently modified by solution! This is clearly not always the case as we can see in areas that have not been subjected to glaciation such as Chillagoe and the Nullarbor. OK, the Nullarbor and Kongorong might not be etched into 'roughly rectangular blocks' but …

Whatever, pavements are often the palette on which much karren is initiated. Assuming the sculptor – solution – has a palette? Other karren is found on sloping and vertical surfaces.



Pavement

Above. Yorkshire, UK. This is a typical karst pavement first shaved horizontally by glacial action and then modified by solution etching out the joints to produce grikes (the trenches, kluftkarren) and clints (the blocks). Note the sandstone blocks – glacial 'erratics' transported from elsewhere. http://www.limestone-pavements.org.uk/images/irrat_bolders.jpg

Top right. Chillagoe, Qld. Ignore the 'R' unless you are into Richer Slopes. The pavement, 'P', is most definitely not the result of glacial action but is simple solution of the limestone pediment. The clints and grikes are more mature than the Yorkshire example. Photo: Ken Grimes

Middle right. Pyrenees, France (near Gouffre de la Pierre Saint Martin). Alpine karrenfield (lapiés) with many features including dissected pavements, clint and grikes – and maybe a hint of a doline beyond the pavement. Photo: Kevin Kiernan

Bottom right. Mount Owen, South Island, NZ. High altitude, glaciated and perhaps smoothed by overlying snowpack. Note the incipient heelsteps (trittkarren) eroding up and back onto the smoothed surface of the clint. Photo: Kevin Kiernan

Pavement

Kongorong, Mount Gambier, SA. Again a pavement not produced by glacial action but by simple lowering of the bedrock surface. The soil-filled grikes can be metres deep. Photo: Steve Bourne

Kongorong, Mount Gambier, SA. This paddock was a karst pavement but has been "improved" for farming with the use of heavy rock-breaking machinery. Photo: Steve Bourne

Grikes (kluftkarren): Deep clefts, from 1 cm to 0.5 m across and up to several metres deep. They are one of the most typical mesokarren features, normally from 1 m to 10 m in length, formed through the simple solutional enlargement of joints or cracks. Their linear trends are determined by major structural directions as joint sets or faulting. Owing to the fact that such slots cut in the bedrock are merely the visible surface expression of the fissures crisscrossing the karstifiable rocks, grikes constitute a significant component of the epikarst.

Giant grikes *. Above Mimbi Cave, West Kimberly, WA. Giant grike network – up to five metres wide. Note the vertical wall karren (wandkarren) and the relatively undisected surface of the giant clints/pavement. Photo: Joe Jennings*

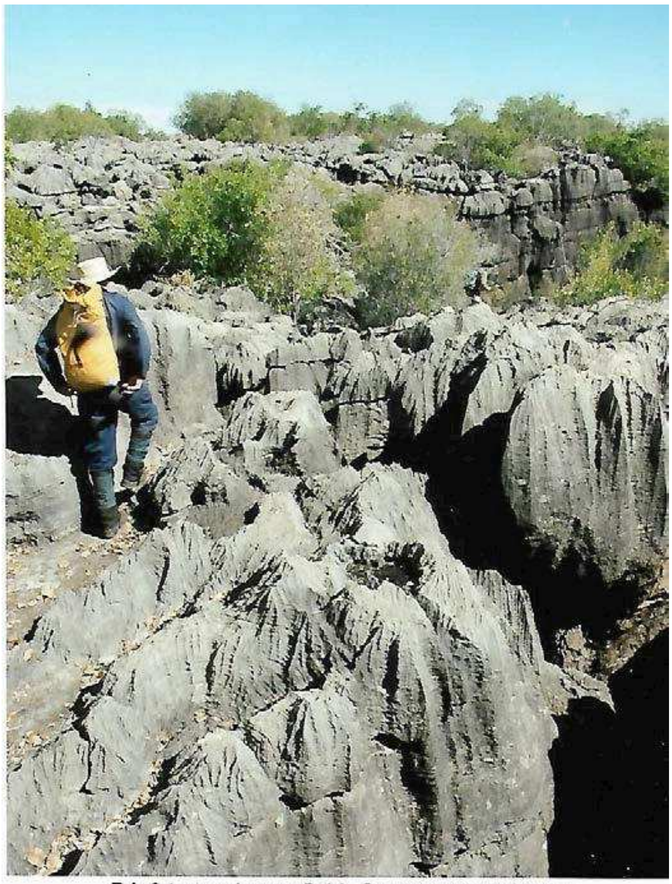
Pinnacles (spitzkarren): Vertical solution along joints and fractures lowers the intervening rock flanks and produces isolated spires or pinnacles that can reach a few metres or tens of metres in height. Sometimes macrokarren as at Mulu's pinnacles! Usually the side walls are deep grikes with runnels cutting across one another to form sharp ridges and peaks. They could be considered as particularly mature forms of karren. Ginés feels that often they may be sharpened from subcutaneous karren forms. This would appear unlikely for the pinnacles at Mulu, for example.

Wall karren (wandkarren) and pinnacles (spitzkarren)

Above. Wall karren (wandkarren) and pinnacles (spitzkarren) Chillagoe, Qld.

Right. Small pinnacles (spitzkarren) and deep grikes – Gregory Karst, NT. Note the meticulous recording that Ken attached to his images!

Below. Mulu Pinnacles. These are pinnacles – spitzkarren at the top end of the range! Note the small scale solution flutes (rillenkarren) on the rock the lady is ornamenting. Also note the lack of solutionally enlarged horizontal features indicating the massive nature of the limestones at Mulu.
http://1.bp.blogspot.com/-hJw02NyG-Uc/Tc-Tvz4chyI/AAAAAAAAB9o/biU10ksou4o/s1600/P1020602.JPG



BA-34 area karrenfield, Gregory Karst NT.au.
"K3" spitzkarren + deep grikes
D051209 K.G. Grimes, 6-7-2005

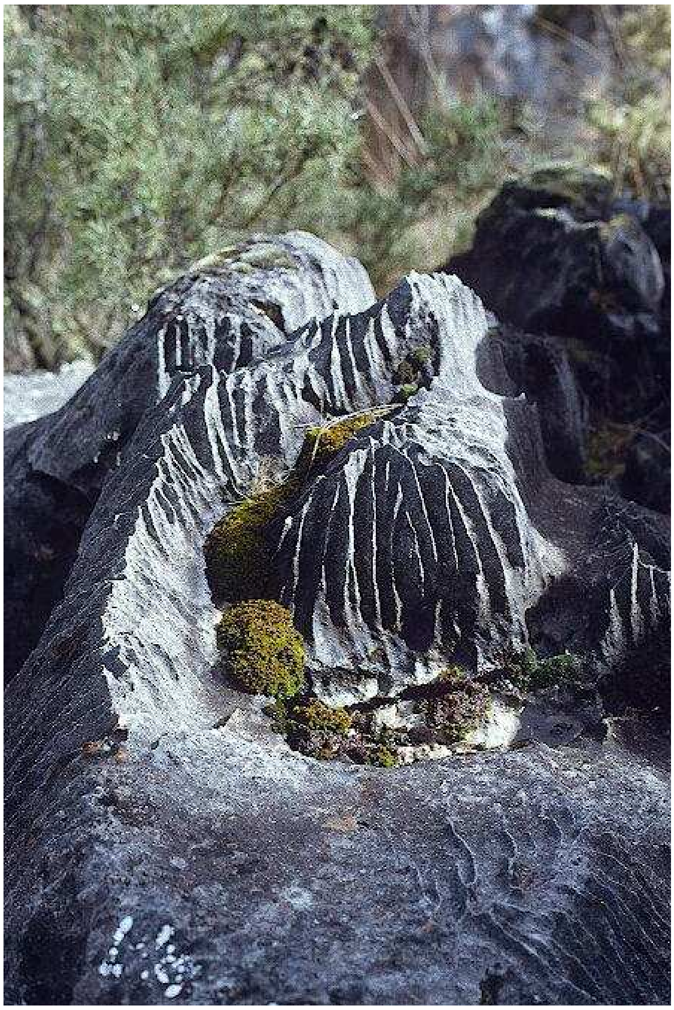
*Broken River, Qld. Ken Grimes amongst a field of pinnacle karren (spitzkarren) standing in a **solution pan (kamenitzas)** modified by **meandering runnels (mäanderkarren**). Turtle Tower is utterly amazing! Photo: Ian Houshold*

*Perue Peak, Prince of Wales Island, SE Alaska. **Grike** intersecting **solution tubes**; clint surface again glaciated. Photo: Kevin Kiernan*

***Meandering runnels (mäanderkarren)** Broken River, Qld. Photo: Ken Grimes*

Meandering runnels (mäanderkarren): Small winding channels that are cut directly into the rock surface or within a larger runnel. This special kind of karren channels exhibit meander forms with typical undercutting and slip-off slopes. There is frequent overlapping between meandering karren and some types of decantation runnels.

Solution runnels (rinnenkarren): Mesokarren features consisting of linear channels or furrows that generally show increased width and depth downslope. Threads of runoff water, pouring down the flanks of the rocks, are collected into channels to create solution runnels whose width and depth range from 5 to 50 cm, being very variable in length (commonly from 1 to 10 m, but in some cases exceeding 30 m long). Owing to the great diversity of topographic conditions and the kind of water supply feeding their channelized flow, they have a remarkable variety in cross section and plan pattern (including tributaries).



Above. Yarrangobilly, NSW. ***Solution flutes (rillenkarren)*** *surrounding a small* ***solution bevel (ausgleichsflächen).*** *Photo: Andy Spate*

Right. Yarrangobilly, NSW. ***Solution flutes (rillenkarren on clints****). Note the moss and other vegetation in the shallow grike around the core. The significance of this is discussed in the caption for solution pans (kamenitzas) below.*

Solution flutes (rillenkarren): Small, straight, narrow, closely packed, parallel solutional furrows, that start at the crest of bare rock slopes and extinguish downslope. Their dimensions in limestone outcrops are typically 1.2-2.5 cm in width, 2-6 mm in depth and 10-30 cm in length or longer. (If longer they usually start to develop into wider karren forms). Individual flutes are parabolic in cross-section and are separated by sharply pronounced cusp lines. In plan view, they may form a simple suite of parallel flutes showing remarkable regularity of form and dimension. Their development to either side of a crest often produces a typical herringbone pattern – sometimes swirly.

Solution bevels (ausgleichsflächen): Lovely word! Allows you swear at the visitors – unless they speak German. Flat, smooth surfaces, 0.2 to 1 m long, usually found as plane sub-horizontal belts developed below the level of rillenkarren-flutes extinction.

Heelsteps (trittkarren): Conspicuous karren features that form arcuate headwalls, which flat floors are open in downslope direction. A single trittkarren consists of a flat tread-like surface, 10 to 40 cm in diameter, and a sharp back-slope or riser, 3 to 30 cm in height. Their typical appearance is as groups of heel prints excavated as steps on the rock outcrops. They seem to be the result of complex solutional processes involving both horizontal and headward corrosion generated by the thinning of water sheets flowing upon small slope falls.

Solution ripples: Wave-like forms, transverse to downward water movement under gravity. Their rhythmic forms suggest that periodic pulses of flow or chemical changes are important in their development. Joe Jennings suggested many years ago that, as they seem to occur most frequently in windy areas that wind pulsating on the water film may play a role.

Heelsteps (trittkarren)

These are exceptionally developed – probably in an alpine environment. http://www.neko.ch/wp-content/uploads/2016/07/06_Tannenstockkarst_Trittkarren_20Juli16MTruessel.jpg

Solution pans (kamenitzas): Dish-shaped depressions, 1 cm to 50cm deep, 5 cm to 5 m wide and mostly elliptical or circular to highly irregular in plan. Usually they have flat and nearly horizontal bottoms that are floored by a thin layer of soil, vegetation or algal remains which decay enhances further dissolution. Their borders are frequently overhanging and may have small overspill outlets. At least one at Yarrangobilly does not have flat floor but has small spikes to ~3 mm height across the floor cracks. Their linear trends are determined by major structural directions as joint sets or faulting. Owing to the fact that such slots cut in the bedrock are merely the visible surface expression of the fissures crisscrossing the karstifiable rocks, grikes constitute a significant component of the epikarst.

Yarrangobilly, NSW. Joe Jennings measuring the acidity of water in a ***solution pan****. The decaying vegetation will enhance solution.*

Clints (flachkarren): Tabular intervening blocks or slabs isolated by grikes. They are flat or gently inclined outcropping rocks which become divided into straight-sided blocks by the solutional widening of fissures. These bare flat surfaces of limestone, generally parallel to the bedding (no, no!), are the main constituent of limestone pavements.

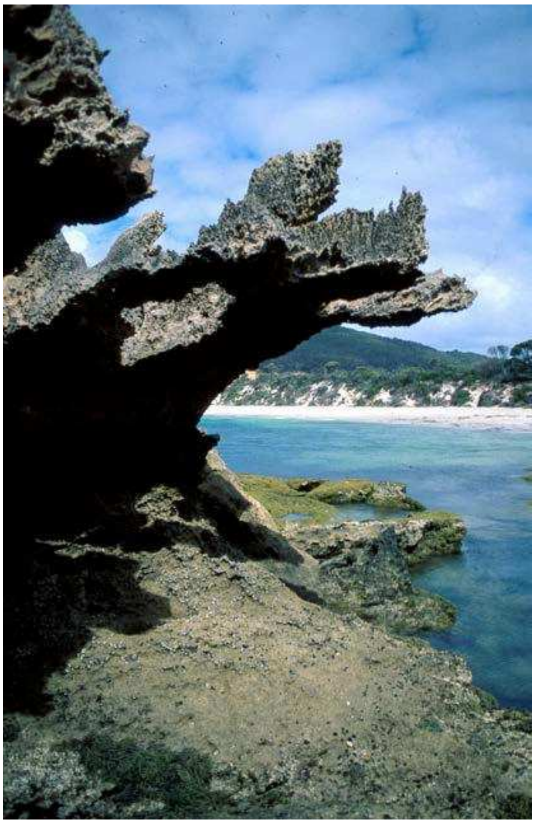
Microrills (rillensteine): Microkarren features characterized by rock surfaces showing several different patterns formed by tiny channels and/or micro-spikes, rarely surpassing 1 mm in width. They have been typically described as about 1 mm wide rills, round bottomed and packed together with characteristic tightly sinuous to anastomosing plan view patterns on gentle slopes, becoming more parallel and straighter with increasing slope.

Rainpits (solution pits): Small, hollowed cuplike karren features, sub-circular in plan and nearly parabolic or tapering in cross section, whose diameter ranges from 1 cm to 5 cm, and exceptionally exceeding 2cm in depth. Frequently appear clustered in groups and can coalesce to give irregular and carious (having many cavities like your teeth before fluoridation of water appeared) appearance to the rock surfaces.

Decantation runnels: Channels generated by water released steadily, that start from an upslope point-located store (e.g. a patch of moss) or from a diffuse or linear source (e.g. a bedding plane) situated upwards. Generally their cross-sections are largest close to the input of water and diminish downslope.

Cooleman Plains, NSW. ***Solution pans (kamenitzas),*** *some over-deepened. Where soil, decaying vegetation and plants accumulate in the bottom of solution pans more carbon dioxide and organic acids accelerate deepening of the pans and grike floors. Note, the tear-drop shaped pan is aligned along and unseen joint that can be traced to the right. The development of the small solution flutes around the pans is inhibited by the short path length available. Photo: Andy Spate*

Cooleman Plains, NSW. ***Subsoil karren****. Smoothly shaped features such as these are typical of karren formed within soils. Where these are seen at the surface they are indicative of recent soil erosion. The limestones of Central Western NSW (e.g. at Molong) show that sometimes as much as a metre of soil has been lost since Europeans arrived. Photo: Andy Spate*



Above. Cooleman Plains, NSW. ***Solution ripples****. These are found in sub-alpine to alpine areas. Jennings (per. comm.) attributed them to winds rippling a film of surface water as it flows down the rock surface. Photo: Andy Spate*
Right. Flinders Island, Tasmania. Coastal Karren. The spiky karren is often referred to as phytokarst (first described from the Island of Hell in the Caribbean – the name arises from the difficulty of crossing such terrains). Seawater in spray mixed with rainwater, plus algae etc., enhances solution to rapidly produce such forms in 'soft' limestones. The term phytokarst is used incorrectly in other contexts.

Cooleman Plains, NSW. This "history block", being studied by Joe Jennings and Bao Hao Sheng, shows a number of features of interest. The observers have their hands on typical above-ground weathering. Since European settlement, with intensive grazing and rabbits, a creek has removed the soil in front of the rock. Three stages of incision can be seen. The first is the smooth area below the top indicating that the stream removed soil quickly. The band of scalloping below, shows a long period of stream flow eroding the limestone. Renewed incision by the stream has quickly removed the soil revealing traces of shallow, rounded solution runnels.

Rounded runnels (rundkarren): Channels or furrows developed beneath a soil cover, whose troughs and ribs become smoothed by the more active corrosion associated with soil waters that produces their characteristic rounded cross-sections.

Subsoil smooth surfaces (subcutaneous karren forms): A whole array of characteristic rounded and smooth rock surfaces appear clearly related to subsoil corrosion. Smoothing and bleaching of subsoil karren-forms is evident when it is compared with the sharpening and grey appearance of exhumed karren forms. Subsoil smoothing can be considered a consequence of specific nanokarren features developed in contact with the action of acidic soil water.

Subsoil hollows (subcutaneous hollow-forms): Subsoil hollows showing different shapes and sizes are frequently exposed in road cuts and quarry walls. They are also common at the foot of karren pinnacles. In addition to pockets, niches and recesses, great subsoil wells and small subsoil pitting and scallop-like features are frequently found.

Undercut runnels (hohlkarren): Mesokarren furrows transformed by organic debris or partial soil filling because their side walls have been hollowed under by enhanced biogenic carbon dioxide concentration. Typical bag-like cross sections, wider at the bottom than at the top, are generated in this way. Undercutting is often also seen in solution pans as they accumulate organic material that provides acidity to dissolve away our limestone at the margins.

The images below are not karren but are small scale landform features found in limestone and other rocks.

Above left and right. Cooleman Plain, NSW. A-tent or pop-up. These fragile features are found on flat or gently sloping surfaces where overlying sediments which have compacted the rocks below, and have later been removed by solution. The compacted surface layer expands to relieve the tension induced by the formerly overlying materials. The process appears to be sudden. These at Cooleman Plain range in length from a few tens of centimetres to about two metres with the gap beneath in the largest of 10-15 centimetres.
Photos: Andy Spate

Below. Wudinna Rock, Eyre Peninsula, SA. This A-tent, in granite, is a much larger feature – and not so fragile! The slab thickness approaches a metre. Interpretative material at this site suggests that the slabs have extended by 3-4% as they popped up. Well worth a visit on your way to the Nullarbor. Photo. Kirsty Dixon